



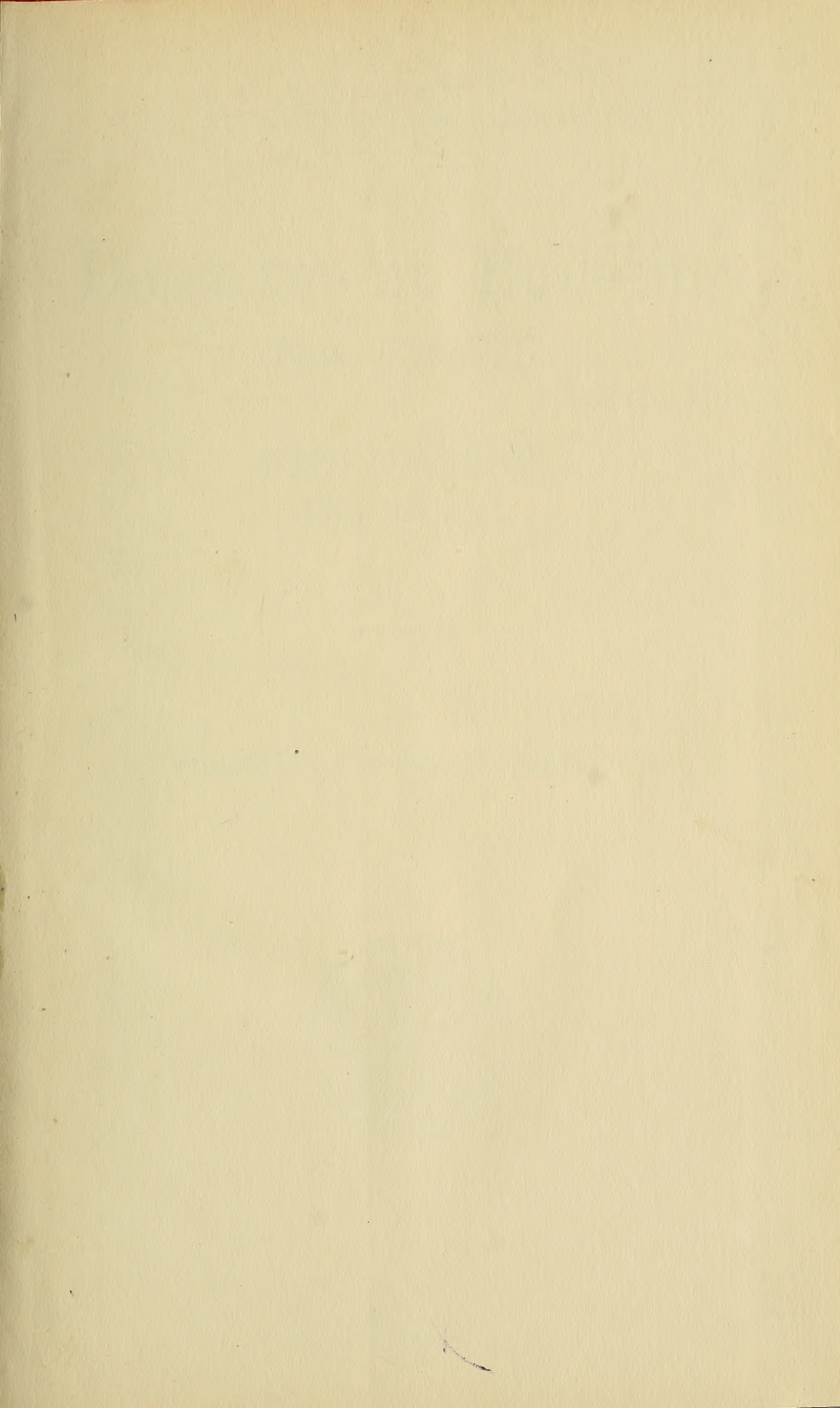
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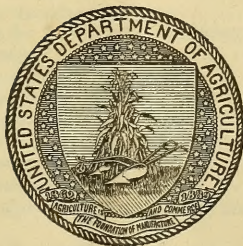
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EXPERIMENTS WITH SINGLE-STALK COTTON CULTURE IN LOUISIANA, ARKANSAS, AND NORTH CAROLINA.

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IMPORTANCE OF SINGLE-STALK COTTON CULTURE.

Single-stalk cotton culture was first announced as a new system in 1913, and at that time also its principles were outlined.¹ Since that year three additional publications² have been issued, which present results obtained in 1913 and 1914 from experiments with the system in Virginia, South Carolina, and Texas. The purpose of this report is to present the results obtained in 1915 from a series of experiments conducted in the States of Louisiana, Arkansas, and North Carolina.

The single-stalk system is based on the recognition of a fact that has not been taken into practical account in most of the cultural

¹ Cook, O. F. A new system of cotton culture. U. S. Dept. Agr., Bur. Plant Indus. Cir. 115, p. 15-22, 1913.

² Cook, O. F. A new system of cotton culture and its application. U. S. Dept. Agr., Farmers' Bul. 601, 12 p., 2 fig. 1914.

Cook, O. F. Single-stalk cotton culture. U. S. Dept. Agr., Bur. Plant Indus. [Misc. Pub.] 1130, 11 p., 12 fig. 1914.

Meade, R. M. Single-stalk cotton culture at San Antonio. U. S. Dept. Agr. Bul. 279, 20 p., 3 fig., 6 pl. 1915.

experiments that have been made with cotton, namely, that the cotton plant has two distinct kinds of branches, vegetative and fruiting, and that the relative growth of these can be controlled by cultural methods. Single-stalk cotton culture differs from systems usually employed in two essential features, namely, the time of thinning and the spacing of plants in the row. Where the usual methods involve thinning the seedlings soon after complete germination and spacing to distances varying with the locality from 12 to 30 or more inches, single-stalk culture involves later thinning and closer spacing, down to 6 inches, or even less under some conditions.

The purpose of the later thinning is to suppress the development of vegetative branches, which usually are produced at the lower nodes of the main stalk. If cotton plants are left close together in the row during the early stages of their growth, few vegetative branches are likely to develop, for the buds at the lower nodes of the main stalks remain dormant, and only fruiting branches appear at the upper nodes. So in applying single-stalk culture, thinning is delayed until after the suppression of vegetative branches has been accomplished and until fruiting branches are expected to appear. Then the plants are spaced only far enough apart to allow for the normal development of the fruiting branches. The distance at which single-stalk plants may be spaced to advantage will depend upon local conditions, differing with soil and climate and the variety used, but, owing to their narrow, erect form the plants may be left much closer together than usual without danger of injurious crowding. In fact, single-stalk rows usually are less crowded than those in which the plants, thinned early and wide spaced, have been allowed to develop fully their long basal limbs, which often equal or even exceed in size the main stalk of the plant.

Owing to the suppression of excessive vegetative growth on single-stalk plants, they usually reach maturity in a shorter time than the more bushy plants. While fewer bolls per plant may be produced, single-stalk rows usually contain a greater total number of bolls and hence give larger row yields than rows grown by the usual systems of culture. Another important feature of single-stalk culture is that, where later thinning is practiced, greater protection is afforded against damage from inclement weather or other injuries to which the seedlings are subject, particularly leaf-cut or tomosis.¹ An additional advantage of later thinning lies in the opportunity to take out weak or injured plants when the thinning is done, so that only normal individuals are left, a condition which increases the yield and earliness of the crop.

¹ Cook, O. F. Leaf-cut, or tomosis, a disorder of cotton seedlings. *In* U. S. Dept. Agr., Bur. Plant Indus. Cir. 120, p. 29-34, 1 fig. 1913.

The success attained in early experiments with single-stalk culture led to a belief that it should prove advantageous under a variety of conditions existing in the cotton belt. The idea of suppressing the vegetative branches was first developed and applied in connection with the production of Egyptian cotton in the Southwest, where it proved to be of distinct value in checking the rank growth of the plants, which for a time threatened the success of the industry.¹ Later, at Norfolk, Va., where the season is relatively short, single-stalk culture gave significantly larger and distinctly earlier yields than the older methods with which it was compared. Similar results have since been obtained in South Carolina with both Sea Island and Upland cotton, and also in Texas, where the most striking advantages have been shown under extreme conditions both of drought and of weevil infestation. These early experiments showed that the system could be used to advantage under a very wide range of conditions, but a large amount of experimental work still remains to be done in order to determine how to secure the best results with the system under any given combination of local conditions of soil, season, and variety of cotton.

The results of these experiments indicate that single-stalk culture may be profitably applied under a wide range of natural conditions, but definite recommendations can not be made for all localities, as it is recognized that a thorough knowledge of local conditions and familiarity with the new system are essential to its successful application. It is not expected that experiments with the new system will show advantages under all conditions, and in some instances unfavorable results may be secured, as has been recorded by the Bureau of Entomology in connection with tests conducted by that Bureau in Louisiana in 1915. Such cases may enable the experimenter to understand the nature and practical limitations of the system and to determine under what conditions of climate, soil, etc., it may be a desirable method for the cotton grower to adopt.

LOCALITIES WHERE EXPERIMENTS WERE MADE.

The present experiments were located in the States of Louisiana, Arkansas, and North Carolina. The parishes and counties in which the work was done, the farmers conducting the experiments, their post-office addresses, and the agents cooperating are listed in Table I.

¹ For a general statement of the cultural difficulties encountered and the means employed in surmounting them, see Scofield, C. S., Kearney, T. H., Brand, C. J., Cook, O. F., and Swingle, W. T., Community production of Egyptian cotton in the United States, U. S. Dept. Agr. Bul. 332, 30 p. 1916.

TABLE I.—*List of localities where experiments in single-stalk cotton culture were conducted in 1915, showing cooperators therein.*

State and parish or county.	Farmer.	Address.	County agent.
Louisiana:			
Pointe Coupee.....	John Hebert.....	Ventress.....	Felix Dabadie.
Do.....	Alfred Robillard.....	do.....	Do.
Madison.....	Killarney Plantation.....	Mounds.....	T. I. Watson.
Do.....	R. K. Boney.....	Duckport.....	Do.
Do.....	R. C. Webb.....	Delta Point.....	Do.
Bossier.....	Essie Jackson.....	Benton.....	E. S. Burt.
Do.....	W. B. Wilbourn.....	do.....	Do.
Caddo.....	C. C. Herndon.....	Shreveport.....	A. J. Scott.
Do.....	William Mercer.....	Gilliam.....	Do.
Jackson ¹	L. M. Calhoun, jr.....	Gilbert.....	L. M. Calhoun.
Arkansas:			
Miller.....	D. R. Akin.....	Fouke.....	T. F. Lueker.
Do.....	J. E. Tanner.....	Texarkana.....	Do.
Do.....	W. B. Latta.....	do.....	Do.
North Carolina:			
Edgecombe.....	W. K. Benson.....	Battleboro.....	Zeno Moore.
Do.....	L. L. Draughon.....	Whitakers.....	Do.
Do.....	W. R. Felton.....	Conetoe.....	Do.
Sampson.....	H. D. Sloan.....	Ingold.....	MacD. Davis.
Do.....	W. I. Wright.....	do.....	Do.
Do.....	L. F. Green.....	do.....	Do.
Duplin.....	L. M. Sanderson.....	Warsaw.....	D. J. Middleton.
Craven.....	J. L. Roper.....	Riverdale.....	J. W. Sears.
Do.....	B. C. Peterson.....	Vanceboro.....	Do.

¹ Three experiments were conducted at this point. When the farms were visited on August 13, 1915, the conditions all appeared favorable to single-stalk culture. However, repeated requests have failed to bring any report of the final results obtained, so these experiments can not be included herein.

In the case of some of the farmers listed in the table, as will be pointed out later, relatively poor stands were obtained, for which certain allowances must be made. In most of the cases in which the stands were uniformly good, a fairly adequate comparison of methods was possible; but in others, as will be shown, thinning certainly was done too late to secure the best results, and in some instances the crop may have been injured in this way.

METHODS OF PROCEDURE.

SELECTION OF COOPERATORS.

The county agents selected from among the farmers in their respective counties (or parishes) a few of those who were most interested and gave evidence of being able to carry out instructions. They are not necessarily the best farmers in their respective counties, but they are representative of the better farmers. Their farms are so distributed as to afford conditions fairly typical of those over a large part of each State, except in the case of Arkansas, where flood damage resulted in the abandonment of most of the experiments that were begun. Although the experiments in North Carolina were confined to the eastern district, a large part of the total cotton-growing acreage of the State is represented. In Louisiana, experiments were conducted in sections typical of the larger areas of the State where cotton is grown.

PLAN OF THE EXPERIMENTS.

The county or parish agents were requested to make arrangements with the farmers for conducting the experiments on ordinary fields of cotton, planted and cultivated in the usual manner. It was suggested that a more accurate comparison of the systems of culture employed would be possible if the methods were compared in alternate rows and in alternate blocks of 4 or 5 rows. To do this it would be necessary to thin at the usual time each alternate row or block and leave the others for later thinning. In several instances this plan was followed, but in some instances comparisons were made only in alternate rows. In one case in Louisiana an entire acre, located in the center of a field of several acres, was grown by the single-stalk method.

THINNING SINGLE-STALK ROWS.

Any intelligent grower, after a little careful observation, can tell when to thin; but for the purpose of these experiments it was considered more dependable actually to demonstrate the method than merely to issue written instructions. Accordingly, some one familiar with the new system directed the thinning of the single-stalk rows in most of the experiments. The few farmers whose farms it was impracticable to visit at this time thinned according to written instructions, and these experiments were, with one or two exceptions, fairly dependable.

The general advantage obtained in applying single-stalk culture is the suppression of vegetative branches. The distance at which the plants should stand in the row is a secondary consideration and must be regulated to suit local conditions, but as a rule the largest yields have been obtained with the plants much closer together than is now customary. Accordingly, the plants in the single-stalk rows of these experiments were spaced 6 to 10 inches, the standard aimed at being about 8 inches. The plants as thinned by the farmers in the old-method rows were variously spaced, according to usual practice, 18 to 36 inches.

RECORDING THE YIELDS.

The recording of yields in each case was left with the farmer, who in some instances was assisted by the county agent. However, it was requested that the yield from each row at each picking be recorded separately, and blanks for this purpose were furnished. Row yields were reported by 17 of the 21 farmers, while only total yields were reported by 4 farmers. The general rule followed was to have the picking done from only one row at a time and have the yield of that row recorded before proceeding to the next.

RESULTS OBTAINED.

As these experiments were largely demonstrational, it is of chief importance to consider their economic phases. While more detailed reports of the flower counts, boll counts, branch measurements, etc., would be of interest from the standpoint of a scientific consideration of the factors involved, these data are treated only incidentally in this report. The interest at this time lies in knowing whether single-stalk culture increased the yield of seed cotton, whether it had any effect on the percentage of lint, and whether the quality of the lint was in any way affected.

YIELDS OF SEED COTTON.

The experiments are herein discussed by States, in the following order: Louisiana, Arkansas, North Carolina. In presenting the yields of seed cotton obtained, each experiment is first considered in detail, apart from the others. A summary table, bringing together the total yields of all the experiments, is then presented to facilitate comparisons.

LOUISIANA.

The nine different experiments conducted in Louisiana, all under boll-weevil conditions, are considered by parishes, as follows: Pointe Coupee, in the south-central part of the State; Madison, in the north-eastern part; Bossier and Caddo, in the northwestern part.

POINTE COUPEE PARISH.

Two experiments were conducted in Pointe Coupee Parish, on the farms of Messrs. John Hebert and Alfred Robillard, near Ventress. They were about a quarter of a mile apart. Both are located on sandy soil, typical of that drained by the Mississippi River in this part of Louisiana, and in each instance the cotton was planted on low beds in rows $4\frac{1}{2}$ feet apart. Unfavorable weather influenced both crops early in the season, wet weather during March being followed by drought.

The Hebert experiment.—Mr. John Hebert planted Sugarloaf cotton on May 10, which was considered unusually late in this section. He planted at the rate of 25 pounds per acre, which was heavier than usual. Germination was good, and an almost ideal stand was secured. Single-stalk culture was compared with the usual method in alternate rows, there being 14 rows of each.

The old-method rows were thinned on May 25, when the plants, 3 to 4 inches high and with 2 to 3 leaves, were spaced about 18 inches apart. When the single-stalk rows were thinned on June 6, the plants were 10 to 12 inches high and had 6 to 8 leaves. They were spaced 6 to 10 inches apart. Had the thinning of the single-stalk rows been done a little earlier, it is likely that it would have been

better, but, as Table II shows, significant differences in yield were obtained. Only the total yields of each picking were reported.

TABLE II.—*Yields, obtained in a single-stalk culture experiment with cotton conducted in 1915 by John Hebert, Ventress, La.*

Spacing system.	Yield of seed cotton (pounds).		
	First picking.	Second picking.	Total.
Single-stalk rows, thinned June 6.....	505	350	855
Old-method rows, thinned May 25.....	380	300	680
Difference:			
Pounds.....	125	50	175
Per cent.....	32.9	16.7	25.7

Table II shows single-stalk culture to have had a marked advantage from the standpoint of earliness as well as of total yield. Single-stalk culture yielded 32.9 per cent more cotton at the first picking than the old method, and 16.7 per cent more at the second picking. This gave an increase in total yield of 25.7 per cent.

The Robillard experiment.—Mr. Robillard planted Bank Account cotton on May 6, using only 15 pounds of seed per acre. Only a fair stand was obtained; the seedlings were somewhat scattered and in some rows there were short skips. This made it impossible to apply single-stalk culture to the best advantage. Moreover, Mr. Robillard spaced the plants in the single-stalk rows farther apart than was recommended. There were 20 rows in the experiment, the two systems of culture being compared in alternate rows.

The old-method rows were thinned on May 19, when the plants were 4 to 5 inches high and had 2 to 3 leaves; the single-stalk rows were thinned on June 8, when the plants were about 10 inches high and had 7 to 8 leaves. The plants in the old-method rows were spaced 18 to 24 inches apart, and in single-stalk rows 10 to 12 inches.

Three pickings were made in this experiment, and the yields are reported in Table III. Only the total yields of each picking were reported.

TABLE III.—*Yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by Alfred Robillard, Ventress, La.*

Spacing system.	Yield of seed cotton (pounds).			
	First picking.	Second picking.	Third picking.	Total.
Single-stalk rows, thinned June 8.....	226	211	169	606
Old-method rows, thinned May 19.....	177	178	134	489
Difference:				
Pounds.....	51	33	35	117
Per cent.....	28.8	18.6	26.1	23.9

Table III shows that the increase in yield from each picking favored single-stalk culture by 28.8, 18.6, and 26.1 per cent, respectively, giving a total increase of 23.9 per cent.

MADISON PARISH.¹

Three experiments were conducted in Madison Parish, located at intervals of about 5 miles between Tallulah and Delta Point, the latter bordering on the Mississippi River. Two of these were on sandy alluvial soil, and the other was on heavy buckshot soil, both soils being fairly representative of types found in that section, known as the Delta. In all cases the cotton was planted on low beds in rows about 4 feet apart. Spring conditions were unfavorable generally, a wet March being followed by drought through April and May.

The Killarney experiment.—This experiment was on buckshot soil located on the Killarney Plantation, at Mounds. Owing to the poor stand obtained from the first planting, a second planting of Simpkins cotton was made on April 15, and a fairly good stand was secured. On June 3, a few plants from the first planting were visible in the single-stalk rows and it was suggested that at thinning time, about a week distant, these older plants be removed, since there were enough of the younger plants for single-stalk purposes. To leave the older ones would have resulted in nonuniformity. Mr. T. I. Watson, parish agent, directed this later thinning.

The old-method rows were thinned on May 22, when the plants, 4 to 6 inches high and with 3 to 5 leaves, were spaced 18 to 30 inches apart. The single-stalk plants, thinned on June 12, when they were 8 to 10 inches high and had 6 to 8 leaves, were spaced 8 to 10 inches apart.

In practically all of the rows of this experiment there were a few skips 3 feet or more in length. Toward the end of the season the skips appeared to be greater in the aggregate in the wide-spaced rows than in the single-stalk rows, and this was doubtless a factor in the increased yields, as often occurs with the new system. Prior to the time of thinning the wide-spaced rows, the stand of all the rows was so uniform that no appreciable differences in the number and length of skips per row were perceptible. Any differences of soil

¹ In reporting the yields from the experiments made in Madison Parish, Parish Agent T. I. Watson told of the results of an informal experiment with single-stalk culture conducted on his own initiative by Mr. N. C. Williamson, of Millikin, East Carroll Parish, La. Mr. Williamson applied single-stalk culture on 2 acres. Of the yields obtained, Mr. Watson said:

I was at his [Williamson's] place on November 24 and secured his yield, which was 1,300 pounds of lint from the 2 acres, or an average of 650 pounds of lint per acre. His general crop is making about 1,280 pounds of seed cotton per acre, or 80 bales on 100 acres. Mr. Williamson does not consider that he carried out the method fully enough to be recognized as an experiment, but thinks well of it and says he is going to try it out next year.

Mr. Williamson's crop of 80 bales of lint from 100 acres is equivalent to about 400 pounds of lint per acre. Compared with this, as reported by Mr. Watson, the 2 acres of cotton grown by the single-stalk method yielded an average of 650 pounds of lint. On the basis of these figures, it is seen that single-stalk culture yielded 250 pounds of lint per acre, or about 62 per cent, more than the old method.

or other local conditions would tend to be equalized by the alternate-row method of comparing the two systems of culture. But more numerous and wider skips often appear in wide-spaced rows on account of injury to seedlings, due to greater exposure in the early stages of their development. Fewer plants are injured in single-stalk rows because of the mutual protection afforded by the thick-standing seedlings, and such injuries as occur are rendered unimportant because enough plants remain to thin as desired. This feature has been previously pointed out as one of the many advantages of later thinning.¹

There were 16 rows in the experiment, the two systems being compared in alternate rows. Two pickings were made, but the yields from only the first picking were reported. These are shown in Table IV.

TABLE IV.—Row yields of the first picking obtained in a single-stalk culture experiment with cotton conducted in 1915 on the Killarney Plantation at Mounds, La.

Row.	Yield of seed cotton (pounds).		Row.	Yield of seed cotton (pounds).	
	Single stalk.	Old method.		Single stalk.	Old method.
No. 1.....	35	29	No. 7.....	38	27
No. 2.....	43	28	No. 8.....	33	20
No. 3.....	33	24			
No. 4.....	38	26	Total.....	287	207
No. 5.....	35	25	Difference.....	80	
No. 6.....	32	28	Increase.....per cent..	39	

Table IV shows that in this experiment single-stalk rows yielded more cotton in every instance than adjoining old-system rows, the total increase for the first picking being 39 per cent. Judging by the appearance of the rows in August, when counts of immature bolls were made by Mr. Watson and the writer, showing 75 to 100 per cent more bolls on the single-stalk rows than on the others, it is believed that the difference in yield from the second picking, had it been recorded, would have been even greater than 39 per cent. But even if it were no greater, or considerably less, the difference in the first picking is of marked significance, since the experiment was located in a section of maximum boll-weevil infestation, where earliness in the cotton crop is of the greatest importance.

The Boney experiment.—This experiment was on sandy soil located on the farm of Mr. R. K. Boney, at Duckport. Half-and-Half cotton was planted under fairly desirable conditions (date and rate not reported) and a good stand was secured. Definite details concerning the time of thinning the old-method rows and their condition when thinned were not reported. The plants in these rows were spaced,

¹ See Cook, O. F. Leaf-cut, or tomosis, a disorder of cotton seedlings. In U. S. Dept. Agr., Bur. Plant Indus. Cir. 120, p. 29-34, 1 fig. 1913.

however, 18 to 24 inches in the row. When inspected on June 3, the old-method plants were branching normally, indicating fairly early thinning. At this time, also, the plants in the single-stalk rows were rather too far advanced for the best results, numerous fruiting branches being visible. Although thinning was completed within the two days following, on June 4 and 5, it is reasonable to assume that more significant results would have been obtained had thinning been done several days earlier. When thinned the plants were 8 to 12 inches high with 6 to 8 leaves. With a long-staple variety, this would have been more nearly the proper time to thin, but with Half-and-Half, a short-staple cotton, it unquestionably was too late. The plants were spaced about 8 inches apart.

There were 12 rows in the experiment, and the two systems of culture were compared in alternate rows. Two pickings were made, the yields of each row for each picking being as reported in Table V.

TABLE V.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 on the farm of R. K. Boney, Duckport, La.*

Row.	Yield of seed cotton (pounds).					
	First picking.		Second picking.		Total.	
	Single stalk.	Old method.	Single stalk.	Old method.	Single stalk.	Old method.
No. 1.....	38	34	16	24	54	58
No. 2.....	34	35	31	24	65	59
No. 3.....	38	34	29	22	67	56
No. 4.....	40	30	27	21	67	51
No. 5.....	35	35	24	21	59	56
No. 6.....	42	38	22	28	64	66
Total.....	227	206	149	140	376	346
Difference.....	21		9		30	
Increase..... per cent.	10		6		9	

Table V shows that the yield per row at each picking favored single-stalk culture in all but 4 instances, in one of which the yields were identical. In total yield, single-stalk culture led in four of the six rows. The total yield at each picking favored single-stalk culture by 10 and 6 per cent, respectively, the total increase for both pickings being 9 per cent. This difference is considerably less than was forecast by boll counts made on August 14, when it was found that single-stalk rows had from 40 to 50 per cent more bolls than old-method rows. The chief reason for this discrepancy between the boll counts and the yields reported may lie in the probability that more bolls opened earlier on the single-stalk rows than on the old-method rows and more of the cotton on the former was lost before picking time. This explanation appears the more credible if we take into account the fact that varieties of the type used in this experiment are lacking in stormproof qualities.

The Webb experiment.—Mr. R. C. Webb, of Delta Point, planted Money Maker cotton on sandy soil on April 20 at the rate of three pecks per acre. The stand secured was poor generally, there being also a number of skips in each row. Owing to nonuniformity in germination, there were, moreover, plants of various sizes in the single-stalk rows at thinning time. The smaller plants were still too young to have had their vegetative branches completely suppressed, while the larger plants had reached the stage where their fruiting branches were being suppressed. Since it was necessary to leave plants of all sizes in the row in order to have the spacing as uniform as possible, some allowances should be made in considering the results of the experiment.

There were 30 rows in the experiment and the two systems of culture were compared in alternate rows. The old-method rows were thinned on May 20, when the plants were 4 to 5 inches high and had 3 to 4 leaves. The single-stalk rows were thinned on June 6, when the plants were 6 to 12 inches high and had 6 to 10 leaves. The plants in the old-method rows were spaced 18 to 24 inches apart, while the single-stalk plants were spaced at about 8 inches wherever the stand permitted such close spacing.

Two pickings were made, the yields from each row for each picking being as shown in Table VI.

TABLE VI.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 on the farm of R. C. Webb, Delta Point, La.*

Row.	Yield of seed cotton (pounds).					
	First picking.		Second picking.		Total.	
	Single stalk.	Old method.	Single stalk.	Old method.	Single stalk.	Old method.
No. 1.....	13	13	32	24	45	37
No. 2.....	9	18	25	18	34	36
No. 3.....	18	19	23	22	41	41
No. 4.....	9	13	23	21	32	34
No. 5.....	13	14	32	20	45	34
No. 6.....	11	18	20	18	31	36
No. 7.....	14	18	16	16	30	34
No. 8.....	8	14	14	15	22	29
No. 9.....	13	13	16	20	29	33
No. 10.....	13	18	16	15	29	33
No. 11.....	14	14	17	14	31	28
No. 12.....	14	13	15	12	29	25
No. 13.....	8	18	16	18	24	36
No. 14.....	18	13	15	15	33	28
No. 15.....	18	13	15	14	33	27
Total.....	193	229	295	262	488	491
Difference.....		36	33			3
Increase..... per cent.		19	15			0.6

Table VI shows a difference of 19 per cent in favor of the old system of culture at the first picking. The lower yield of the single-stalk rows at this picking doubtless resulted, as already explained, from the fact that the thinning was done too late in the case of some

plants and too early in the case of others in the same row. However, as often happens in such cases, the difference was practically offset by the yields of the second picking, which favored single-stalk culture by 15 per cent. There was practically no real difference in total yield, though the old system had a very slight advantage. This was contrary to what was to be expected, in spite of the poor stand, as counts of immature bolls made on August 14 indicated an increase for single-stalk culture of 15 to 20 per cent.

BOSSIER PARISH.

Two experiments were conducted in Bossier Parish, both in the immediate vicinity of Benton. One of these was on the farm of Mr. E. S. Burt, parish agent, and was conducted by Essie Jackson, a tenant; the other was on the farm of Mr. W. B. Wilbourn.

The Jackson experiment.—Cotton of the Brown variety was planted April 7 on low beds 4 feet apart. The soil, a sandy loam, was in good condition and a full stand was obtained. Wet weather prevailed during April, followed by dry weather during May, this being unfavorable to good growth.

The old-method rows were thinned on May 17, the plants, which were 3 to 4 inches high with 4 to 5 leaves, being spaced 18 to 24 inches apart. The single-stalk rows were not thinned until June 9, when the plants, being 10 to 14 inches high with 6 to 10 leaves, were spaced about 8 inches apart.

There were 26 rows in the experiment, and the two systems of culture were compared in alternate rows. Two pickings were made. The yields of each row for each picking and the total yields are reported in Table VII.

TABLE VII.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by Essie Jackson on the farm of E. S. Burt, Benton, La.*

Row.	Yield of seed cotton (pounds).					
	First picking.		Second picking.		Total.	
	Single stalk.	Old method.	Single stalk.	Old method.	Single stalk.	Old method.
No. 1.....	26	30	15	10	41	40
No. 2.....	30	28	15	10	45	38
No. 3.....	26	28	15	15	41	43
No. 4.....	26	26	15	20	41	46
No. 5.....	25	25	20	15	45	40
No. 6.....	28	28	15	15	43	43
No. 7.....	28	28	15	10	43	38
No. 8.....	23	24	15	15	38	39
No. 9.....	28	28	20	10	48	38
No. 10.....	23	23	15	10	38	33
No. 11.....	28	28	15	10	43	38
No. 12.....	23	18	10	10	33	28
No. 13.....	22	24	10	10	32	34
Total.....	336	338	195	160	531	498
Difference.....		2	35	.....	33	.....
Increase..... per cent.		0.6	22	.....	7	.....

Table VII shows a slight increase in the total yield from the first picking in favor of the old method, though in only 4 of the 13 instances did old-method rows yield more than single-stalk rows. In 7 instances the yields were identical. It is believed that the reason for this difference in yield at the first picking may be found in the fact that the single-stalk rows were thinned much later than was advisable, some suppression of the lower fruiting branches already having taken place. By the time the second picking was made this handicap had been overcome and the single-stalk rows yielded 22 per cent more cotton than the others, making a total increase in yield of 7 per cent.

An interesting point in regard to the value of single-stalk culture under conditions conducive to unusually rank growth was observed in connection with this experiment. A hogpen once stood near one end of several of these rows and the soil here was much richer than elsewhere in this field. The cotton plants grew to heights of 5 to 7 feet and put on a dense foliage. The plants in the early-thinned wide-spaced rows threw out long vegetative branches, and when nearing maturity these settled to the ground, in many cases breaking away from the main stalk and in all cases obstructing the space between the rows. It was difficult also to pick cotton from these plants, and owing to its being allowed to touch the ground much of the cotton was spoiled. The single-stalk plants, on the other hand, stood erect, their fruit well off the ground and easily accessible. Moreover, the space between these rows was left open enough to allow cultivation.

The Wilbourn experiment.—Cotton of the Brown variety was planted on April 7 in low beds in rows about 4 feet apart, and a fairly good stand was secured. Wet weather prevailed during the remainder of April, followed by drought during May, which was not favorable to good growth.

The thinning of the old-method rows was done on May 17, when the plants were 3 to 4 inches high, with 2 to 4 leaves, while the single-stalk rows were not thinned until June 9, when the plants were about 8 inches high and had 6 to 8 leaves. The plants in the old-method rows were spaced 18 inches apart and those in the single-stalk rows 6 to 8 inches.

There were 40 rows in the experiment and the two systems of culture were compared in alternate rows. Only one picking was made. The yields obtained from each row are reported in Table VIII.

Table VIII shows that in no instance did single-stalk culture yield more than the old method with which it was compared, the total increase for the old method being 17 per cent. This is absolutely the reverse of what was indicated on August 16 by boll counts

made by Mr. E. S. Burt, agent for Bossier Parish; Mr. A. J. Scott, agent for Caddo Parish; and the writer. Then there were 40 to 50 per cent more bolls on the single-stalk rows and it was confidently expected by all present that the yields would vary in about the same proportion, favoring single-stalk culture. It is believed that much of the cotton on the single-stalk rows had fallen from the bolls before picking time, for the crop was not picked until October 26, which was unusually late.

TABLE VIII.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 on the farm of W. B. Wilbourn, Benton, La.*

Row.	Yield of seed cotton (pounds).		Row.	Yield of seed cotton (pounds).	
	Single stalk.	Old method.		Single stalk.	Old method.
No. 1.....	35	45	No. 13.....	35	35
No. 2.....	35	45	No. 14.....	35	40
No. 3.....	50	45	No. 15.....	30	40
No. 4.....	35	40	No. 16.....	35	35
No. 5.....	35	45	No. 17.....	30	40
No. 6.....	40	45	No. 18.....	25	30
No. 7.....	30	45	No. 19.....	30	40
No. 8.....	30	35	No. 20.....	25	25
No. 9.....	30	40			
No. 10.....	30	35	Total.....	645	780
No. 11.....	35	40	Difference.....		135
No. 12.....	35	35	Increase.....per cent.		17

CADDO PARISH.

Two experiments were conducted in Caddo Parish, one on the farm of Mr. C. C. Herndon, near Shreveport, and the other on the farm of Mr. William Mercer, at Gilliam, about 20 miles northwest from Shreveport.

While early seasonal conditions in this part of the State were more favorable to the normal growth of the crop than in most other sections, they were not ideal, in that some drought obtained during April and May.

The Herndon experiment.—This experiment was the only one of the series in which single-stalk culture was compared with the usual method on an acre basis. The single-stalk acre was located in a rather low corner of a field of several acres, and it maintained only a fair stand. Moreover, there were several skips in each row. The field was planted rather late in April, and dry weather prevented uniform germination.

There was a difference of only nine days in the time of thinning the two plats in this experiment. The old-method rows were thinned on June 4, when the plants were 3 to 4 inches high and had 2 to 4 leaves, while the single-stalk rows were thinned on June 13, when the plants were 6 to 8 inches high and had 5 to 8 leaves. The plants in the former rows were spaced 18 to 24 inches apart and those in the latter 6 to 8 inches.

The yields reported in Table IX are for the first picking from 10 representative rows in the single-stalk acre and 10 in an adjoining acre. No complete report on the second picking is available.

TABLE IX.—Row yields of first picking obtained in a single-stalk culture experiment with cotton conducted in 1915 on the farm of C. C. Herndon, Shreveport, La.

Row.	Yield of seed cotton (pounds).		Row.	Yield of seed cotton (pounds).	
	Single stalk.	Old method.		Single stalk.	Old method.
No. 1.....	13	11	No. 8.....	13	11
No. 2.....	11	10	No. 9.....	14	12
No. 3.....	12	12	No. 10.....	13	14
No. 4.....	10	11			
No. 5.....	12	12	Total.....	123	112
No. 6.....	12	10	Difference.....	11	.....
No. 7.....	13	9	Increase..... per cent.	9.8	.....

Table IX shows that in 6 out of 10 instances greater yields were obtained from single-stalk rows. In two instances the yields were identical, while in two other instances the old-method yield exceeded the single-stalk yield by 1 pound per row. The total yield of the 10 rows favored single-stalk culture by 9.8 per cent.

The Mercer experiment.—While Mr. William Mercer, of Gilliam, cooperated in this work on the same basis as other farmers, he was left much alone in the conduct of his experiment. It was impracticable to visit his field at thinning time, and consequently he thinned his cotton according to his interpretation of the general instructions offered. At all times, however, he cooperated with Mr. A. J. Scott, county agent. No report of how he planted his cotton or the time and method of thinning is available. The only data available are given in Table X.

TABLE X.—Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 on the farm of William Mercer, Gilliam, La.

Row.	Yield of seed cotton (pounds).					
	First picking.		Second picking.		Total.	
	Single stalk.	Old method.	Single stalk.	Old method.	Single stalk.	Old method.
No. 1.....	12	9	2	22	14	31
No. 2.....	10	10	22	22	32	32
No. 3.....	9	10	12	2	21	12
No. 4.....	9	10	12	22	21	32
No. 5.....	10	10	2	22	12	32
No. 6.....	10	9	22	2	32	11
No. 7.....	10	10	22	2	32	12
No. 8.....	10	9	2	2	12	11
No. 9.....	9	10	2	22	11	32
No. 10.....	10	9	2	2	12	11
Total.....	99	96	100	120	199	216
Difference.....	3	.....	.....	20	.....	17
Increase..... per cent.	3	.....	.....	20	.....	8

Table X shows a wide variation in yields from the two systems of culture. In the yields from the first picking, single-stalk culture led in 4 of the 10 instances. In 3 instances the yields were identical and in 3 other instances greater yields were obtained from the old-method rows. The total yield from the first picking was slightly (3 per cent) in favor of single-stalk culture.

In the yields from the second picking, single-stalk culture led in only 3 of the 10 instances, while the old method led in 4. In 3 instances the yields were identical. It is remarkable that the yields throughout differed in about the same proportion. The total yield of the second picking, however, favored the old method of culture by 20 per cent, making an increase of 8 per cent in total yield for this method.

ARKANSAS.

Owing to the damage done by early spring floods, most of the experiments begun in Arkansas were abandoned. The only ones which promised any dependable results were located in Miller County, in the vicinity of Texarkana, and at Warren, in Bradley County. The latter experiment, however, was located in a pecan grove and the trees apparently so reduced the supply of moisture in the soil that when the drought of August was encountered the cotton plants were compelled to shed a large proportion of their squares. This damage, combined with apparent weevil damage, made the test practically without value.

MILLER COUNTY.

The experiments in Miller County were conducted by Messrs. D. R. Akin, J. E. Tanner, and W. B. Latta, the first named being located about 10 miles south of Texarkana, at Fouke, and the others being located in the immediate vicinity of Texarkana. Mr. R. M. Meade, of the Bureau of Plant Industry, visited these experimenters early in June and directed the thinning of the single-stalk rows.

The Akin experiment.—Mr. D. R. Akin, of Fouke, planted Lone Star cotton on May 20, about 15 days later than usual. Unfortunately, only a small amount (12 pounds per acre) of seed was planted, and a relatively poor stand resulted. Wet weather occurred immediately after planting, and this was followed by drought, which caused the surface soil to bake. At the time of thinning the single-stalk rows it was observed that the plants were not standing thick enough to insure complete suppression of the vegetative branches, but enough had been suppressed to make the test worth carrying out.

There were 28 rows in the experiment, 8 in which the two systems of culture were compared in alternate rows and 20 in which comparisons were made in alternate blocks of 5 rows each. The plants in the old-method rows were spaced about 18 inches apart and those in the single-stalk rows about 8 inches, wherever the stand per-

mitted. The exact dates of thinning were not reported, but it is known that the single-stalk rows were thinned later than the others.

In reporting the yields obtained, Mr. Akin stated:

The experiment has not been at all satisfactory to me, owing to several causes: (1) I did not plant enough seed to crowd the cotton sufficiently at the start; (2) the cotton being late, the continuous rains in August caused an enormous amount of blooms to sour and fall off; (3) the boll weevil and bollworms finished what the rain left. However, I thought you might be able to get some data from the report. You will see I had only one picking, no middle or top crop at all.

Mr. Akin stated further that rows 21 to 28, inclusive, were on much richer soil than the others, and he felt that for this reason they were not comparable. The yields from the remaining 18 rows are reported in Table XI. The first four rows were in the alternate-row test; the remaining five were in a 5-row block of adjoining rows.

TABLE XI.—Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by D. R. Akin, Fouke, Ark.

Row.	Yield of seed cotton (pounds).		Row.	Yield of seed cotton (pounds).	
	Single stalk.	Old method.		Single stalk.	Old method.
Alternate rows:			5-row block—Continued.		
No. 1.....	13	9	No. 7.....	15	10
No. 2.....	13	10	No. 8.....	11	11
No. 3.....	13	9	No. 9.....	11	10
No. 4.....	14	10			
5-row block:			Total.....	115	90
No. 5.....	14	9	Difference.....	25	.....
No. 6.....	11	12	Increase.....per cent..	28	.....

Table XI shows that in every instance the alternate-row yields favored single-stalk culture, and in every instance but one the block-test yields favored this system. The total increase for single-stalk culture was 28 per cent.

The Tanner experiment.—Mr. J. E. Tanner, R. F. D. No. 7, Texarkana, planted 60 pounds of Triumph seed per acre on April 18, which was unusually early. The high rate of planting resulted in a good stand, but unsettled weather, accompanied by sudden changes of temperature, caused a very noticeable amount of leaf-cut.¹

Although somewhat later than desirable, it was possible to thin the single-stalk rows in a fairly satisfactory manner; but the yields from these could not be expected to vary much from those of the old-method rows, because the latter were thinned unusually late, accomplishing some suppression of vegetative branches, and the plants were left about as near together as those in the single-stalk rows.

¹ See Cook, O. F. Leaf-cut, or tomosis, a disorder of cotton seedlings. In U. S. Dept. Agr., Bur. Plant Indus. Cir. 120, p. 29-34, 1 fig. 1913.

The early thinning was done on May 10 and the later thinning on June 5. When thinned, the plants in the old-method rows were 4 to 6 inches high and had 4 to 6 leaves, while those in the single-stalk rows were 8 to 10 inches high and had 6 to 8 leaves. The old-method plants were spaced 8 to 12 inches apart and the single-stalk plants 6 to 8 inches apart.

There were 20 rows in the experiment, 10 in which the systems of culture were compared in alternate rows, and 10 in which comparison was made in 5-row blocks of adjoining rows. The yields from each of the two pickings made are reported in Table XII.

TABLE XII.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by J. E. Tanner, Texarkana, Ark.*

Row.	Yield of seed cotton (pounds).					
	First picking.		Second picking.		Total.	
	Single stalk.	Old method.	Single stalk.	Old method.	Single stalk.	Old method.
Alternate rows:						
No. 1.....	8	8	3	4	11	12
No. 2.....	8	6	4	5	12	11
No. 3.....	7	8	4	3	11	11
No. 4.....	7	8	3	3	10	11
No. 5.....	7	8	4	2	11	10
5-row blocks:						
No. 6.....	8	9	4	3	12	12
No. 7.....	8	9	4	2	12	11
No. 8.....	9	9	5	3	14	12
No. 9.....	8	9	3	3	11	12
No. 10.....	9	8	5	3	14	11
Total.....	79	82	39	31	118	113
Difference.....		3	8		5	
Increase.....per cent.		4	26		4	

Table XII shows an increase of 4 per cent in the total yield from the first picking for the old method, doubtless because of the lateness of thinning of the single-stalk rows. But as often happens in such cases there was a greater difference, 26 per cent, in favor of single-stalk culture for the second picking, making the total yield 4 per cent greater for this system.

The Latta experiment.—Mr. W. B. Latta, of Texarkana, used Mebane cotton in two experiments on his farm. One of these was planted on April 25 and the other on May 10. He used about 30 pounds of seed per acre and a good stand was secured on both fields. The thinning of the old-method rows was done at the usual time, May 10 and May 25, respectively, the plants being spaced 12 to 15 inches apart. The single-stalk rows were thinned when the plants were 10 inches high and had 7 or 8 leaves. They were spaced about 6 inches apart.

When inspected late in August, these experiments promised to be very favorable to single-stalk culture, as about 25 per cent more bolls

were found on these rows than on the old-method rows. Unfortunately, however, Mr. Latta failed to report the yields in detail, merely stating that, in the total yield of two pickings, single-stalk culture exceeded the old-system by an average of $1\frac{1}{2}$ pounds per row, or 11 per cent.

NORTH CAROLINA.

Nine experiments were conducted in North Carolina. These were divided among four counties, namely, Edgecombe, Duplin, Sampson, and Craven. While it was possible in all cases to plant cotton at about the usual time, the weather immediately following was unfavorable to normal growth, being wet and cold. Consequently some poor stands were obtained, and in certain instances considerable difficulty was encountered in getting the single-stalk rows thinned in proper time.

EDGECOMBE COUNTY.

There were three experiments in Edgecombe County, one each at Whitakers, Battleboro, and Conetoe, all being located on soil classed as Norfolk sandy loam. The cotton was grown in rows 3 to 4 feet apart, planted flat; that is, not in beds. A rather heavy rate of seeding was used in all cases and good stands were secured. It was impossible for the writer or any of his associates to inspect these experiments in time to direct the thinning of the single-stalk rows, so Mr. Zeno Moore, county agent, directed it on the basis of his understanding of the new system.

The Benson experiment.—Mr. W. K. Benson, of Battleboro, planted Ricks, a short-limbed variety of cotton, on April 22, using one bushel of seed per acre, and a good stand was obtained. The old-method rows were thinned on May 22, the plants being 2 to 3 inches high and having 2 to 4 leaves. The single-stalk rows were thinned on June 24, when the plants were 8 to 10 inches high and had 10 to 12 leaves. The plants in the old-method rows were spaced about 14 inches apart, while those in the single-stalk rows were spaced 6 to 8 inches apart.

In submitting the above data, Mr. Moore reported that the rows were not thinned with "perfect regularity." When visited by the writer in August, it appeared that the plants in the single-stalk rows were left too thick, there being, in the majority of cases, 2 to 3 plants in a hill. The suppression of vegetative branches had been accomplished and probably to some extent that of the fruiting branches as well. This may account for the greater yield obtained on the old-system rows at the first picking, as shown in Table XIII.

Table XIII shows that a greater yield, of 22 per cent, was obtained from the old-system rows at the first picking, but a greater yield, of 353 per cent, was obtained from the single-stalk rows at the second picking, making the total yield favor single-stalk culture by 20 per

cent. The greater yield of the old-method rows at the first picking is in itself an evidence of the fact that the thinning of the single-stalk rows was too late to give the best results, but, as not infrequently happens, the loss was more than made good by the increased yield of the single-stalk rows at the second picking.

TABLE XIII.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by W. K. Benson, Battleboro, N. C.*

Row.	Yield of seed cotton (pounds).					
	First picking.		Second picking.		Total.	
	Single stalk.	Old method.	Single stalk.	Old method.	Single stalk.	Old method.
No. 1.....	51	49	35	24	86	73
No. 2.....	51	65	34	14	85	79
No. 3.....	53	62	38	9	96	71
No. 4.....	53	71	43	8	96	79
No. 5.....	53	63	40	11	93	74
No. 6.....	58	72	37	7	95	79
No. 7.....	64	80	35	5	99	85
No. 8.....	60	72	32	.....	92	72
No. 9.....	59	78	32	.....	91	78
No. 10.....	57	74	27	.....	84	74
Total.....	564	686	353	78	917	764
Difference.....		122	275	.....	153	.....
Increase.....per cent..		22	353	.....	20	.....

The Draughon experiment.—Mr. L. L. Draughon, of Whitakers, used Cleveland Big Boll cotton in his experiment, there being 28 rows in all. The two systems of culture were compared in alternate rows. Thinning was completed in a fairly satisfactory manner, though a little later than was advisable for single-stalk culture.

Mr. Draughon reports that it was impossible to get pickers in time for the first picking and consequently the cotton remained unpicked until late in November. Undoubtedly much cotton was lost meantime, particularly from the single-stalk rows. Only total yields were reported, and these were 1,074 pounds for single-stalk culture and 1,004 for the old method, a difference of 70 pounds, or 7 per cent, in favor of single-stalk culture.

The Felton experiment.—Mr. W. R. Felton, of Conetoe, chopped the single-stalk rows of his experiment in such a manner as to leave the plants standing in bunches, which, however, probably suppressed the development of vegetative branches in much the same manner as single-stalk culture. He reported the yields which are given in Table XIV. Only one picking was made, on November 2, probably after some cotton had fallen from the bolls.

Table XIV shows that in all but 4 of the 14 instances, single-stalk rows yielded more cotton than old-system rows, giving an 8 per cent increase for the new method. In reporting the above yields Mr. Felton stated: "I am satisfied that the thick rows would have made a better showing had they been properly thinned."

TABLE XIV.—*Row yields of the first picking obtained in a single-stalk culture experiment with cotton conducted in 1915 by W. R. Felton, Conetoe, N. C.*

Row.	Yield of seed cotton (pounds).		Row.	Yield of seed cotton (pounds).	
	Single stalk.	Old method.		Single stalk.	Old method.
No. 1.....	52	30	No. 10.....	42	38
No. 2.....	40	36	No. 11.....	44	42
No. 3.....	40	46	No. 12.....	42	38
No. 4.....	44	44	No. 13.....	38	32
No. 5.....	44	40	No. 14.....	40	46
No. 6.....	42	36			
No. 7.....	38	40	Total.....	582	540
No. 8.....	38	36	Difference.....	42	-----
No. 9.....	38	36	Increase.....per cent.	8	-----

SAMPSON COUNTY.

Three experiments were conducted in Sampson County, all in the immediate vicinity of Ingold, on sandy-loam soil. The writer directed the thinning of the single-stalk rows in the latter part of June, when it was found that had thinning been done a week or 10 days earlier it would have been far more favorable. Still, fairly satisfactory comparisons of the new with the old system of culture were possible.

The Sloan experiment.—Mr. H. D. Sloan planted Prolific cotton, of the King type, on April 20, and a good stand was secured in spite of unfavorable weather. The old-method rows were thinned on May 25 and the single-stalk rows not until June 28. The plants in the former rows were 3 to 4 inches high with 3 to 5 leaves, and they were spaced 18 inches apart. In the latter rows the plants were 8 to 10 inches high with 6 to 10 leaves, and they were spaced 6 to 8 inches apart.

There were 30 rows in the experiment, 20 in which the systems of culture were compared in alternate rows and 10 in which comparison was made in adjoining blocks of 5 rows each. Only one picking was made. The yields reported by Mr. Sloan are given in Table XV.

TABLE XV.—*Row yields of the first picking obtained in a single-stalk culture experiment with cotton conducted in 1915 by H. D. Sloan, Ingold, N. C.*

Row.	Yield of seed cotton (pounds).		Row.	Yield of seed cotton (pounds).	
	Single stalk.	Old method.		Single stalk.	Old method.
Alternate rows:			Adjoining blocks:		
No. 1.....	46	41	No. 11.....	48	37
No. 2.....	44	38	No. 12.....	49	41
No. 3.....	44	36	No. 13.....	48	39
No. 4.....	45	42	No. 14.....	46	37
No. 5.....	47	38	No. 15.....	47	38
No. 6.....	46	36			
No. 7.....	48	39	Total.....	699	582
No. 8.....	47	42	Difference.....	117	-----
No. 9.....	48	38	Increase.....per cent.	20	-----
No. 10.....	46	40			

Table XV shows that in each of the 15 instances single-stalk culture gave a greater yield than the old system, the total increase being 117 pounds, or 20 per cent.

The Wright experiment.—Mr. W. I. Wright planted one-half bushel of Simpkins cotton per acre on April 20. Owing to unfavorable weather, only a poor stand was obtained, and later the stand was further reduced by aphids, causing much leaf-curl. There were several short reaches in each row, however, where it was possible to apply single-stalk culture. It was believed that these places would affect the total yield of the rows to a degree which would indicate what might have been expected had it been possible to apply the method the full length of the rows.

The old-method rows were thinned on May 25, when the plants were 3 to 5 inches high and had 3 to 5 leaves. It was possible to space the plants in these rows about 18 inches apart with fair regularity. In the single-stalk rows, which were thinned on June 25, when the plants were about 10 inches high and had 6 to 8 leaves, the plants were spaced about 8 inches apart wherever the stand permitted.

There were 16 rows in the experiment, each 408 yards long. In 10 of these, comparisons were made in alternate rows; in the 6 remaining rows the comparison was made in adjoining blocks of 3 rows each. Two pickings were made. The yields obtained, as reported by Mr. Wright, are given in Table XVI.

TABLE XVI.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by W. I. Wright, Ingold, N. C.*

Row.	Yield of seed cotton (pounds).					
	First picking.		Second picking.		Total.	
	Single stalk.	Old method.	Single stalk.	Old method.	Single stalk.	Old method.
Alternate rows:						
No. 1.....	211	194	39	37	250	231
No. 2.....	177	158	43	44	220	202
No. 3.....	177	153	45	51	222	204
No. 4.....	154	146	48	50	202	196
No. 5.....	179	137	43	32	222	169
Adjoining blocks:						
No. 6.....	209	187	34	37	243	224
No. 7.....	193	184	37	41	230	225
No. 8.....	197	188	35	33	232	221
Total.....	1,497	1,347	324	325	1,821	1,672
Difference.....	150			1	149	
Increase..... per cent..	11			0.3	9	

Table XVI shows that in each of the eight instances single-stalk culture yielded more cotton at the first picking, the total difference being 150 pounds, or 11 per cent. At the second picking the old method had a very slight, quite negligible, advantage. In total yield the single-stalk rows had an advantage of 9 per cent. The

increase in yield probably would have been greater had the stand been such as to allow the application of single-stalk culture throughout the entire length of the rows.

The Green experiment.—Mr. L. F. Green obtained a very poor stand in his field of Cleveland Big Boll cotton and it was possible to apply single-stalk culture to only a few places in each of the rows reserved for this method. Owing to the fact that the land had been heavily fertilized the plants grew very rank, and when the parts of the rows to which single-stalk culture was applied were thinned the plants had attained a point in their development a little beyond that at which they might have been thinned to the best advantage. The data pertaining to the time of thinning, the condition of the plants at thinning time, and the spacing are the same as those reported for Mr. Wright's experiment except that the plants were a little taller and had 2 or 3 more leaves.

The yields from the only picking made, as reported by Mr. Green, are given in Table XVII.

TABLE XVII.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by L. F. Green, Ingold, N. C.*

Row.	Yield of seed cotton (pounds).		Row.	Yield of seed cotton (pounds).	
	Single stalk.	Old method.		Single stalk.	Old method.
No. 1.....	80	71	No. 9.....	75	65
No. 2.....	80	80	No. 10.....	75	65
No. 3.....	75	68	No. 11.....	77	60
No. 4.....	76	78			
No. 5.....	82	75	Total.....	850	782
No. 6.....	83	80	Difference.....	68	.....
No. 7.....	70	75	Increase.....per cent..	9	.....
No. 8.....	77.	65			

Table XVII shows a total increase for single-stalk culture of 9 per cent, which probably would have been greater had the stand been such as to permit the application of single-stalk culture to the entire length instead of to only a few parts of each row.

DUPLIN COUNTY.

The Sanderson experiment.—The experiment conducted by Mr. L. M. Sanderson, at Warsaw, was the only one in Duplin County. He planted Cleveland Big Boll cotton on April 25 at the rate of 3 pecks per acre, and a fair stand was obtained in spite of unfavorable weather. Mr. G. S. Meloy, of the Bureau of Plant Industry, directed the thinning of the single-stalk rows and reported that it was completed in good time. The old-method rows were thinned on June 6, when the plants were 3 to 4 inches high and had 3 to 4 leaves. The single-stalk rows were thinned on June 17, when the plants were 8

to 10 inches high and had 6 to 7 leaves. The plants in the former rows were spaced 15 to 18 inches apart, those in the latter 4 to 6 inches.

There were 20 rows in the experiment, and the two systems of culture were compared in pairs of rows—that is, two single-stalk rows alternated with two old-system rows, making 5 pairs of rows for each system. Only one picking was made, and this was delayed until late in November, at which time, it was reported, all the bolls were open. Whether much cotton had fallen to the ground meantime can not be stated; but it is safe to assume that some had fallen, especially from single-stalk rows, which probably were earlier than the others. The row yields, as reported by Mr. Sanderson, are given in Table XVIII.

TABLE XVIII.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by L. M. Sanderson, Warsaw, N. C.*

Row.	Yield of seed cotton (pounds).		Row.	Yield of seed cotton (pounds).	
	Single stalk.	Old method.		Single stalk.	Old method.
No. 1.....	91	84	No. 8.....	95	74
No. 2.....	69	76	No. 9.....	89	85
No. 3.....	87	58	No. 10.....	51	72
No. 4.....	74	72			
No. 5.....	68	83	Total.....	765	722
No. 6.....	68	52	Difference.....	43	.....
No. 7.....	73	66	Increase.....per cent..	6	.....

Table XVIII shows that in 7 of the 10 instances single-stalk culture yielded more than the old method, the differences varying from 2 to 21 pounds per row. In the remaining three instances the old method gave greater yields, varying from 7 to 21 pounds per row. The total yield favored single-stalk culture by 43 pounds, or 6 per cent.

Craven County.

Two experiments were conducted in Craven County—one by J. L. Roper, at Riverdale, and another by B. C. Peterson, at Vanceboro.

The Roper experiment.—Mr. W. M. Laughinghouse, superintendent of the Rockwell Farm of J. L. Roper, at Riverdale, planted cotton on May 11 in rows 4 feet apart on flat land, using 1 bushel of seed per acre. A good stand was secured, but dry and cold weather during May and early June checked growth materially. No definite information concerning the dates of thinning and the condition of the plants when thinned is available, but the plants in the old-method rows were spaced at 20 inches in the row as compared with 2 to 6 in the single-stalk rows. The thinning was done by Mr. Laughinghouse as suggested by Mr. J. W. Sears, county agent. It was not practi-

cable for the writer or any of his associates to inspect this experiment at any time during the season.

There were 18 rows in the experiment, and the two systems of culture were compared in alternate rows. Three pickings were made, and the row yields for each picking as reported by Mr. Laughinghouse are given in Table XIX.

TABLE XIX.—Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by Supt. W. M. Laughinghouse on the Rockwell Farm of J. L. Roper at Riverdale, N. C.

Row.	Yield of seed cotton (pounds).							
	First picking.		Second picking.		Third picking.		Total.	
	Single stalk.	Old method.	Single stalk.	Old method.	Single stalk.	Old method.	Single stalk.	Old method.
No. 1.....	63	48	58	55	5	7	126	110
No. 2.....	66	45	53	41	4	3	123	89
No. 3.....	71	51	42	33	6	3	119	87
No. 4.....	82	71	43	24	6	2	131	97
No. 5.....	73	68	47	25	7	3	127	96
No. 6.....	74	60	43	32	6	5	123	97
No. 7.....	81	59	18	27	6	2	105	88
No. 8.....	59	58	31	21	4	6	94	85
No. 9.....	51	50	27	16	3	2	81	68
Total.....	620	510	362	274	47	33	1,029	817
Difference.....	110	-----	88	-----	14	-----	212	-----
Increase..... per cent..	22	-----	32	-----	42	-----	26	-----

Table XIX shows that single-stalk culture yielded more than the old method in every instance but three, namely, the second picking of row 7 and the third picking of rows 1 and 8. Single-stalk culture yielded 110 pounds, or 22 per cent, more at the first picking; 88 pounds, or 32 per cent, more at the second picking; and 14 pounds, or 42 per cent, more at the third picking, making a difference in total yield of 212 pounds, or 26 per cent.

The Peterson experiment.—Mr. B. C. Peterson, of Vanceboro, planted King cotton on April 23. The soil used was sandy loam and the cotton was planted on low beds in rows 4 feet apart, about one-half bushel of seed per acre being the rate used. The seed germinated fairly well, but wet and cold weather following injured the stand, leaving several skips in each row. While these skips were not serious in the old-method rows, in the single-stalk rows they prevented a satisfactory test of this system. The fact that it was possible to apply single-stalk culture to parts of the rows, however, makes it possible to gain from the yields reported an idea of what might have been expected had it been possible to apply the system to the entire length of the rows.

There were 20 rows in the experiment, and the two systems of culture were compared in alternate rows. The old-method rows were thinned on May 23, when the plants, which were 4 to 6 inches

high and had 4 to 6 leaves, were spaced 16 inches apart. The single-stalk rows were thinned on June 24, when the plants, 8 to 10 inches high with 10 to 12 leaves, were spaced 6 to 8 inches apart.

Only one picking was made. The yield of each row as reported by Mr. Peterson is given in Table XX.

TABLE XX.—*Row yields obtained in a single-stalk culture experiment with cotton conducted in 1915 by B. C. Peterson, Vanceboro, N. C.*

Row.	Yield of seed cotton (pounds).		Row.	Yield of seed cotton (pounds).	
	Single stalk.	Old method.		Single stalk.	Old method.
No. 1.....	57	66	No. 8.....	69	68
No. 2.....	62	57	No. 9.....	76	70
No. 3.....	60	56	No. 10.....	70	63
No. 4.....	56	61			
No. 5.....	69	62	Total.....	649	631
No. 6.....	66	69	Difference.....	18	
No. 7.....	64	59	Increase.....per cent..	3	

Table XX shows that in 7 of the 10 instances single-stalk rows yielded more than the old-method rows. The difference in total yield, however, due largely to a poor stand, was only 18 pounds, or 3 per cent, in favor of single-stalk culture.

TABULAR SUMMARY.

The yields of seed cotton obtained from the 21 experiments discussed in the preceding pages are summarized in Table XXI.

TABLE XXI.—*Summary of yields obtained in 21 single-stalk culture experiments with cotton conducted in 1915 in 9 parishes and counties in Louisiana, Arkansas, and North Carolina.*

Picking and method.	Yield of seed cotton (pounds).																		
	Louisiana.								Arkansas.			North Carolina.							
	Hebert.	Robillard.	Killamey.	Boney.	Webb.	Jackson.	Wilbourn.	Herndon.	Mercer.	Akin.	Tanner.	Latta. ¹	Benson.	Draughon.	Felton.	Sloan.	Wright.	Green.	Sanderson.
First picking:																			
Single stalk.....	505	226	287	227	193	336	645	123	99	115	79	...	564	1,074	582	699	1,497	850	765
Old method.....	380	177	207	206	229	338	780	112	96	90	82	...	686	1,004	540	582	1,347	782	722
Second picking:																			
Single stalk.....	350	211	...	149	295	195	...	...	100	...	39	...	353	...	...	...	324	...	362
Old method.....	300	178	...	140	262	160	...	...	120	...	31	...	78	...	...	...	325	...	274
Third picking:																			
Single stalk.....	...	169	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	47
Old method.....	...	134	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	33
Total:																			
Single stalk.....	855	606	287	376	488	531	645	123	199	115	118	...	917	1,074	582	699	1,821	850	765
Old method.....	680	489	207	346	491	498	780	112	216	90	113	...	764	1,004	540	582	1,672	782	722
Increase (per cent):																			
Gain or loss (—)																			
for single stalk...	26	24	39	9	—0.6	7	—17	10	—8	28	4	11	20	7	8	20	9	9	6
																			26
																			3

¹ Actual yields not reported.

In six of the nine experiments conducted in Louisiana the total yield of seed cotton favored single-stalk culture by 9 to 39 per cent. In the other three experiments the total yield favored the old method by 0.6, 8, and 17 per cent, respectively. In the latter instance only one picking was made, and this so late that it is feared some cotton was lost, particularly from the single-stalk rows, which probably opened earlier than the others; also the reports of this experiment are so defective as to throw some doubt upon their record value. In the second instance the experiment was not inspected by the writer and only the yield records are available, so that it can not be stated with assurance that single-stalk culture was properly applied. In the first instance the stand was so poor that the new system could not be applied to good advantage, and it appears, moreover, that the first picking was made too late to secure the full yield. More than one picking was made from six of these experiments. In four of the six instances single-stalk culture yielded 3 to 32.9 per cent more seed cotton at the first picking. The yields from the other two experiments were influenced by thinning that was too late and by a poor stand, respectively. In five of six instances single-stalk culture yielded 6 to 22 per cent more at the second picking. A third picking was made in only one instance, and this favored single-stalk culture by 26.1 per cent.

There were three experiments in Arkansas, and in total yield these favored single-stalk culture by 4, 11, and 28 per cent, respectively. In one instance, where thinning was done a little too late, the old method yielded 4 per cent more seed cotton at the first picking, but this was offset by a 26 per cent increase for single-stalk culture at the second picking.

In all of the nine experiments in North Carolina, single-stalk culture gave greater total yields than the older methods, the differences varying from 3 to 26 per cent. In one instance, where the time of thinning was too late, the old method gave 22 per cent more seed cotton at the first picking, but this was offset by a 353 per cent increase for single-stalk culture at the second picking. In another instance, where three pickings were made, single-stalk culture yielded more seed cotton at each picking than the old method, the difference for each picking being 22, 32, and 42 per cent, respectively.

YIELD AND QUALITY OF LINT.

Having seen the effectiveness of single-stalk culture in increasing the yield of seed cotton over that of the usual systems of culture, it is of importance to know whether the lint was affected by the new system. It might be expected that the suppression of vegetative branches and the closer spacing of the resultant smaller plants would so affect the yield or quality of lint as largely to offset the advantage

gained through increased yield of seed cotton. This condition does not exist, however, as shown by the results of determinations made in connection with the present experiments and those previously reported.

LINT PERCENTAGES.

Table XXII gives the per cent of lint as determined in samples of seed cotton sent in by five farmers from their respective experiments. Reference to Table I, page 4, will show the locations of these farmers, which fairly represent the general distribution of the experiments. One is in south-central Louisiana, one in northeastern Louisiana, one in southwestern Arkansas near the Arkansas-Louisiana line, and two are in North Carolina. The varieties used in these experiments were, respectively, Half-and-Half, Sugar Loaf, Triumph, Prolific (probably King), and Cleveland Big Boll.

TABLE XXII.—*Percentage of lint in samples of seed cotton taken in five single-stalk culture experiments with cotton conducted in 1915 in Louisiana, Arkansas, and North Carolina.*

Sample.	R. K. Boney.	John Hebert.	J. E. Tanner.	H. D. Sloan.	L. M. San- derson.
Old method:					
No. 1.....	35	35	36	37	36
No. 2.....	37	34	34	35	37
No. 3.....	35	33	33	36	37
No. 4.....	36	33	36	35	39
No. 5.....	38	34	33	35	37
Single stalk:					
No. 1.....	39	34	33	35	36
No. 2.....	37	33	34	35	37
No. 3.....	36	33	35	38	35
No. 4.....	37	33	32	39	37
No. 5.....	32	33	34	37	37
Average:					
Old method.....	36.2	33.8	34.4	35.6	37.2
Single stalk.....	36.2	33.2	33.6	36.8	36.4

Table XXII shows practically no difference in the average percentage of lint obtained under the different systems of culture. The difference is remarkably small in view of the great differences in percentage among the individual samples from some of the experiments. The greatest difference in average percentage of lint is 1.2, and this favors single-stalk culture. In three other instances the differences range from 0.6 to 0.8 per cent in favor of the old method. In the remaining instance the average percentages are identical.

RELATIVE ABUNDANCE OF LINT.

The percentage of lint in itself is no more a safe basis for comparing the effect of different cultural methods than it is for judging the relative value of varieties.¹ The percentage of lint would vary

¹ Cook, O. F. Danger in judging cotton varieties by lint percentages. U. S. Dept. Agr., Bur. Plant Indus. Cir. 11, 16 p. 1908.

Meloy, G. S. Lint percentages and lint index of cotton and methods of determination. U. S. Dept. of Agr. Bul. 644, 12 p., 2 fig. 1918.

materially with the size of the seed if the abundance of lint on the surface of the seed remained constant. Conversely, if the abundance of lint were not constant, the lint percentages might appear uniform even though the size of seed varied considerably. Thus it is desirable to know whether the size of seed and the amount of lint per seed were affected by single-stalk culture. The weight in grams of 100 seeds taken from each of the samples discussed in connection with Table XXII is shown in Table XXIII, together with the lint indexes, or the grams of lint on 100 seeds, of the same samples.

TABLE XXIII.—*Weights of 100 seeds and lint indexes (grams of lint on 100 seeds) of five different varieties of cotton as determined from samples of seed cotton grown in five single-stalk culture experiments with cotton conducted in Louisiana, Arkansas, and North Carolina.*

Sample.	Weight of 100 seeds (grams).					Lint indexes=weight of lint on 100 seeds (grams).				
	R. K. Boney.	John Herbert.	J. E. Tanner.	H. D. Sloan.	L. M. Sanderson.	R. K. Boney.	John Herbert.	J. E. Tanner.	H. D. Sloan.	L. M. Sanderson.
Old method:										
No. 1.....	9.1	9.7	12.0	9.7	12.4	4.9	5.2	6.8	5.7	7.0
No. 2.....	9.7	9.8	13.1	9.4	11.2	5.7	5.1	6.8	5.1	6.6
No. 3.....	9.4	9.7	12.8	10.2	11.8	5.1	4.8	6.3	5.7	6.9
No. 4.....	10.2	9.7	12.6	10.6	11.7	5.7	4.8	7.1	5.7	7.5
No. 5.....	9.6	8.9	13.5	10.3	12.6	5.9	4.6	6.6	5.5	7.4
Single stalk:										
No. 1.....	9.5	10.2	12.7	10.3	11.8	6.1	5.3	6.3	5.5	6.7
No. 2.....	8.9	9.9	11.9	9.6	11.8	5.2	4.9	6.2	5.2	7.0
No. 3.....	9.9	9.4	11.2	9.8	11.7	5.6	4.6	6.0	6.0	6.3
No. 4.....	9.5	9.8	12.6	11.1	11.2	5.6	4.8	6.0	7.1	6.6
No. 5.....	10.6	9.0	12.2	10.1	10.2	5.0	4.4	6.3	5.9	6.0
Average:										
Old method.....	9.60	9.56	12.80	10.04	11.94	5.46	4.90	6.72	5.54	7.08
Single stalk.....	9.68	9.66	12.12	10.18	11.34	5.50	4.80	6.16	5.94	6.52

It will be seen from Table XXIII that, while there was considerable variation in the weights of seed representing either of the systems of culture, the average weight of 100 seeds was about the same for each system. This fact, in addition to the fact that there was no significant difference in the percentage of lint, would indicate that the density of lint on the seeds was about the same under the different systems of culture. That is, we would expect to find that the weight of lint per seed did not vary significantly. The figures in the second part of Table XXIII show that such was the case. The lint index, or the number of grams of lint on 100 seeds, is seen to vary only slightly and in direct proportion to the size of seed.

GRADE AND LENGTH OF LINT.

Samples of lint in each of the experiments discussed in connection with Tables XXII and XXIII were submitted to Mr. Fred Taylor, cotton technologist of the Bureau of Markets, for a report on the grade and length of the lint produced by the different systems of culture. Mr. Taylor's report is embodied in Table XXIV.

TABLE XXIV.—*Grade and length of lint of five different varieties of cotton grown under single-stalk and old-method systems of culture in 1915.*

Grower and system of culture.	Grade.	Length of staple.
R. K. Boney:		<i>Inches.</i>
Old method.....	Strict Middling.....	$\frac{1}{16}$
Single stalk.....	do.....	$\frac{1}{16}$
John Hebert:		
Old method.....	Good Middling.....	$\frac{7}{8}$
Single stalk.....	do.....	$\frac{7}{8}$
J. E. Tanner:		
Old method.....	do.....	1
Single stalk.....	do.....	$1\frac{1}{8}$
H. D. Sloan:		
Old method.....	Strict Low Middling.....	$\frac{11}{16}$
Single stalk.....	do.....	$\frac{11}{16}$
L. M. Sanderson:		
Old method.....	Strict Middling.....	$\frac{11}{16}$
Single stalk.....	Good Middling.....	1

Table XXIV shows that there was practically no difference in the lint from the different systems of culture. In three instances the length of lint was slightly ($\frac{1}{16}$ inch) greater for single-stalk culture, and in two instances the lengths were identical. In no instance did the lint from the old-method samples show any superiority in length or grade over that from the single-stalk samples.

SUMMARY.

Under an informal cooperative agreement with the Office of Extension Work in the South of the States Relations Service, 21 experiments with single-stalk cotton culture were conducted in 1915 in nine parishes and counties of three States, namely, Louisiana, Arkansas, and North Carolina.

These experiments were located in ordinary fields of cotton, single-stalk culture usually being compared with older methods in alternate rows or in alternate blocks of 2, 3, or 4 rows. In one instance the two systems were compared on an acre basis.

In all cases the old-method rows were thinned in the usual manner at the usual time, while the single-stalk rows were thinned later and the plants were left closer together than usual, as is required by this method. In all other respects the rows received identical treatment.

All picking was done under the direction of either the farmer himself or the county or parish agent directly interested and a record of the yields forwarded to Washington.

There was no significant difference in the lint produced by the different systems of culture, the lint percentage, the size of the seed, the lint index (grams of lint on 100 seeds), and the grade and length of lint remaining about the same.

Looking at all of the experiments as a group it is seen that single-stalk culture gave greater total yields in 18 of the 21 instances; it gave greater yields at the first picking in 16 of the 21 instances; it

gave greater yields at the second picking in 9 of 11 instances, and it gave greater yields in the only instances where third pickings were made. While some of the differences are so small as to be insignificant in themselves, there was a general increase throughout the entire series of experiments, in several instances by more than 20 per cent.

Eliminating, for the present, those experiments in which it is known that the thinning of the single-stalk rows was done too late, those in which the stands were generally poor and single-stalk culture was applied to only the short spaces in the rows where the stand permitted the application of the new system, those in which there is no assurance that single-stalk culture was properly applied, and those of which the reports are defective, there remain at least five experiments—three in Louisiana and two in North Carolina—that may be considered as fairly reliable tests of single-stalk culture. The yields of seed cotton from these favored the new system by 20 to 39 per cent.

It is not to be inferred that the particular treatment applied in these experiments is the best development of the single-stalk method or that this method is to be recommended for general application in the States where the experiments were located. The suitability of the new system for any region requires that the local conditions and the behavior of the plants be well understood. How to secure the greatest possible advantage from the control of the branching habits of the plants is a problem worthy of the attention of experimenters who are interested in improving cultural methods with cotton.

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A. C. TRUE, Director



Washington, D. C.

PROFESSIONAL PAPER

July 26, 1917

SOME EXERCISES IN FARM HANDICRAFT FOR RURAL ELEMENTARY SCHOOLS¹

By H. O. SAMPSON, *Assistant in Agricultural Education.*

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INTRODUCTION.

The purpose of this bulletin is to give instruction in the making of useful articles for the school, farm, and home. It is intended primarily for rural school teachers and for pupils of the seventh and eighth grades. The exercises have practical application to the agricultural work of the school and also to the various club projects in agriculture. In some States farm mechanics, or as it is termed, handicraft work, is conducted as a regular club project and is proving to be desirable for this purpose.

Many of the exercises and drawings are compiled from extension bulletins of the different States. Bulletins published by Kansas and Iowa agricultural colleges have been used very freely. In these

¹ Prepared under the direction of C. H. Lane, Chief Specialist in Agricultural Education, States Relations Service.

NOTE.—This bulletin furnishes elementary lessons in farm mechanics and is of interest to teachers and pupils of rural schools in all parts of the United States.

States the handicraft club work has received considerable attention. Others of the exercises are from publications of this department; still others are original with the author, being those he has used in giving instruction in agriculture in public schools and in his work on the farm.

It is hoped that the exercises outlined will suggest many others. A large number of school, farm, and home appliances can be made by schoolboys, and the making of these things trains the hand and the eye and develops habits of accuracy and neatness. The work can be done as a part of the regular school work or during spare time at home. It will be a recreation as well as a benefit.

TOOLS AND THEIR USES.

A large investment in tools is not necessary to carry on this work, and many boys on farms will find all the necessary tools at home.

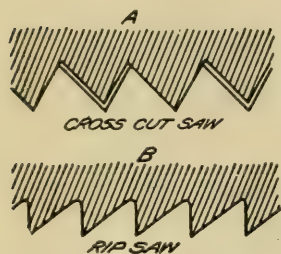


FIG. 1.—Teeth of crosscut and rip saws.

For most of the woodworking exercises the following are sufficient: Crosscut saw, rip-saw, 2-foot rule, steel square, try square, hammer, jack plane, block plane, marking gauge, $\frac{1}{4}$ -inch and $\frac{1}{2}$ -inch chisels, bits and brace, and screw driver. These tools will cost, if purchased new, approximately \$11.

The tools should be of good quality; it seldom pays to purchase inferior ones. Carpenters when buying tools find it economy to select those bearing the stamp of a reliable manufacturer.

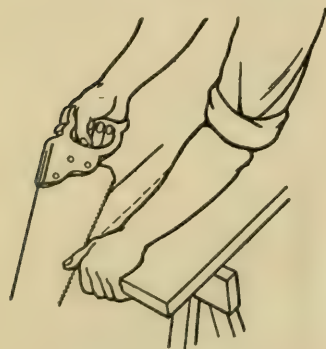


FIG. 3.—Starting the saw.

at A, figure 1. The teeth are usually set or bent alternately so as to be at a slight angle with the body of the saw blade. The insides of the



FIG. 2.—Position of hand, elbow, and shoulder, when using a saw.

All farm boys have had more or less experience with tools and know how to use them fairly well; nevertheless a brief mention of the uses of the tools given in the list will be of value.

The crosscut saw, as the name indicates, is used to cut across the grain of the wood.

Its teeth are filed to sharp points, as shown

teeth are filed in sharpening, as indicated in the figure. The rip saw is used to cut with the grain of the wood. Its teeth are filed to the shape of chisels placed one behind the other, as shown at *B*, figure 1.

Figure 2 shows the position of hand, elbow, and shoulder when using a saw. The index fingers should be along the top of the handle on the right side and the thumb on the left side. They are then in a position to guide the saw. The hand, elbow, and shoulder should be in a straight line, as shown in the drawing. To start sawing, place the left hand on the mark on the board, as shown in figure

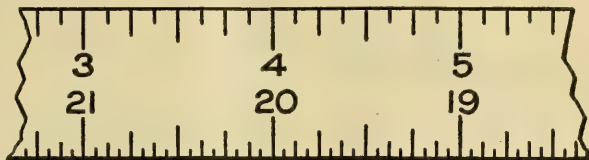


FIG. 4.—Divisions of a carpenter's rule.

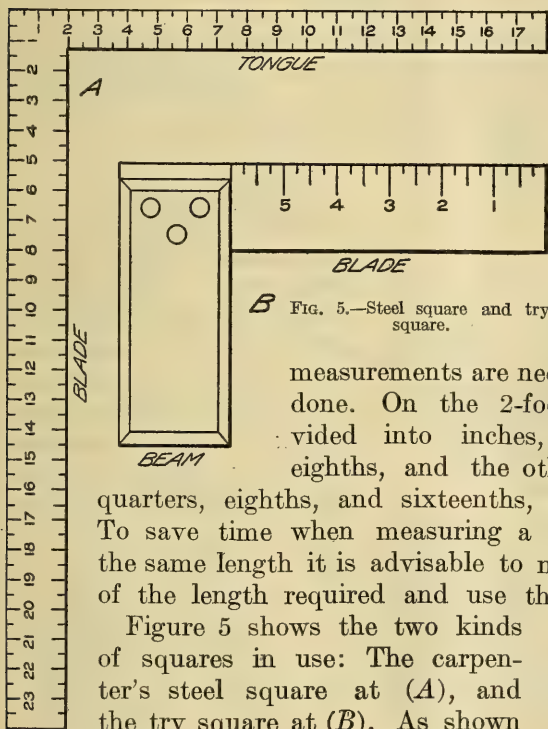


FIG. 5.—Steel square and try square.

3, to guide the saw and make a light up stroke. Continue with a few light strokes up and down until the saw is well started and finally take full strokes the length of the blade. The rule is the measuring gauge. Naturally, accurate measurements are necessary if good work is done. On the 2-foot rule one edge is divided into inches, halves, quarters, and eighths, and the other into inches, halves, quarters, eighths, and sixteenths, as shown in figure 4. To save time when measuring a number of pieces of the same length it is advisable to make a measuring stick of the length required and use this instead of the rule.

Figure 5 shows the two kinds of squares in use: The carpenter's steel square at (*A*), and the try square at (*B*). As shown in the drawing, the parts of

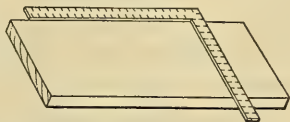


FIG. 6.—Squaring up a board with a steel square.

a steel square are tongue and blade, and the parts of a try square are blade and beam. The carpenter's square is used for measuring lumber and also for squaring across boards when cutting stock into lengths. Figure 6 shows how a steel square is used for squaring across a board. Notice that the long side is parallel with the

length of the board. As the square forms a right angle, the short side will then be at right angles to the sides of the board; consequently, a line drawn on the board along this short side will be at right angles to the side of the board. The try square is used for squaring up boards, as shown in figure 7, and also for testing surfaces and testing angles. Figures 15 and 16, pages 6 and 7, show these operations.

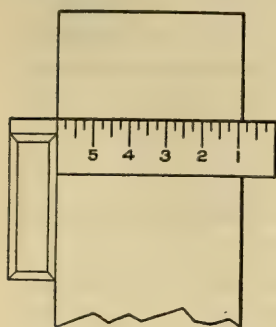


FIG. 7.—Squaring up a board with a try square.

The hammer has two uses—to drive nails, and to pull nails. When driving nails, grasp the handle near the end farthest from the head; you can strike a more effective blow than if you grasp it near the other end. When pulling nails, the hammer acts as a lever; it is surprising how much pulling force is exerted on the nail.

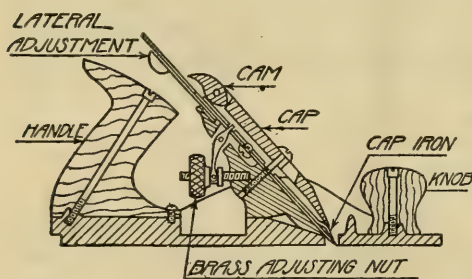


FIG. 9.—Parts of a plane.

plane before you, examine all these parts. When a plane is properly adjusted the plane iron projects the same distance from each side of the throat. The adjustment is tested by sighting, as shown in figure 10, and by feeling with the fingers to see that the edge projects equally on each side.

The marking gauge is used to gauge, or mark, a line parallel to one edge of a board. To set the gauge, hold it point side up in the left hand, and with the rule in the right hand place the end of the rule against the gauge block and see that the measurement desired on the rule is at the point of the gauge, as shown in figure 11. Tighten the set screw, and the tool is ready for use.

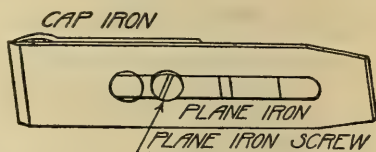


FIG. 8.—Plane iron, plane-iron screw, and cap iron.

The plane is used to smooth surfaces. The jack plane is the one most commonly used. The plane iron is the cutting part of the tool. Figure 8 shows the plane iron, the plane-iron screw, and the cap iron, and figure 9 shows a cross section of a plane with the different parts clearly indicated. With a

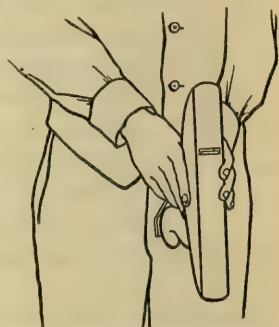


FIG. 10.—Sighting to adjust a plane.

To mark a line, hold the gauge firmly with the thumb and forefinger encircling the gauge block and tip the gauge away from you, as shown in figure 12. To make the line, push the tool—never pull it toward you. Do not press hard against the point—a line only as fine as a knife line is required.

The chisel is used in clipping and paring out portions of wood. When cutting with a chisel, grasp the handle with the right hand and the shank with the left hand and, instead of pushing straight down or straight ahead, incline the tool to get a paring action.

Figure 13 shows the parts of the brace and bit. Unless boring a slanting hole, the bit should enter the wood straight. If the side lips touch the wood at the same time you are sure that the bit has entered the wood straight.

When using a screw driver, be careful not to break the head off the screw. A little soap placed on the screw before inserting it into the wood will make it enter more easily.

CARE OF TOOLS.

FIG. 12.—Method of using the gauge.

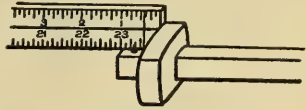
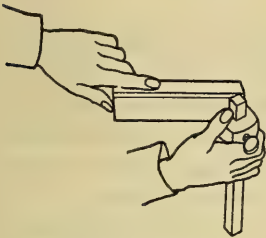


FIG. 11.—Setting the gauge.



If you expect to do good work with tools you must see that they are well cared for. If tools are allowed to become rusty and dull and parts are lost good work can not be expected. Wipe the polished surfaces of tools with an oily cloth once a week, at least, and whenever the bright surface of a tool becomes wet wipe it dry and rub it well with the oily cloth. If rust accumulates, it can be removed by the use of powdered pumice stone.

A place must be provided in which to keep the tools when they are not in use, otherwise they may be lost or broken. Drawers in the work bench, or cupboards placed on the wall where they will be easily accessible, are convenient places for holding tools.

The cutting edges of tools must be kept sharp; good work can not be done with a dull tool. If chisels or plane irons become very dull, they are first sharpened on a grindstone or emery wheel, then dressed on an oilstone. They are ground at an angle of 25° and dressed on the oilstone at an angle of 30° , as shown in figure 14. If but slightly dull they may be rubbed up on the oilstone only. Hold them firmly on the grind-

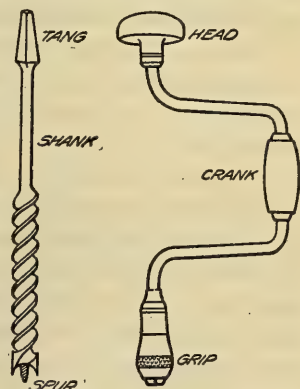


FIG. 13.—Brace and bit.

stone or emery wheel, bevel side down, and grind until a thin wire edge is seen; next, rub them on the oilstone, first on the bevel side and then flat on the stone with the bevel side up. Repeat until the wire edge disappears and the edge becomes sharp.

Saws must be sharp. The sharpening is not an easy matter, and pupils should be aided by some one who has had experience in doing this work.



FIG. 14.—Methods of sharpening tools.

TERMS USED IN WOODWORKING.

Certain terms are used in describing woodworking operations.

These are (1) cutting the stock or lumber, (2) squaring up the stock, (3) laying out the work, (4) cutting to lines, and (5) assembling the parts.

By cutting the stock is meant the getting of the rough pieces of lumber ready to make the article. For finishing, add one-sixteenth inch to the thickness, one-eighth inch to the width, and one-half inch to the length of each piece. The width and thickness of rough lumber are always somewhat less than the stated dimensions. For example, a so-called inch board is usually seven-eighths inch in thickness. This must be kept in mind when cutting stock. Always try to avoid waste. To do this one must measure and calculate carefully before cutting the pieces.

Squaring up the stock means making the rough piece into one that has smooth, flat, straight sides that are at right angles and that is of the desired length, breadth, and thickness. The term "finished stock" is applied to stock that has been squared up. When squaring up stock you should establish a working face and a working edge. To establish a working face plane the board on one side. When planing place the board away from you and push it against the bench stop; begin planing along one edge of the face, take a stroke the length of the board, and continue in this way, moving across the piece. Test the surface by means of the try square. This is done by placing the edge of the square on the planed surface as shown in figure 15, moving it about, and noticing if it touches at all points. If the face is not smooth, as indicated by the try square, continue planing until it is. This smooth face is the working face. Mark it with a cross (X) or some other mark to distinguish it.

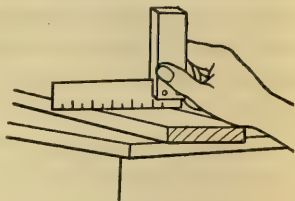


FIG. 15.—Testing the surface.

The working edge is obtained by planing one edge until it is smooth and square with the working face. To test the edge, place the beam

of the try-square against the working face and the blade against the edge, as shown in figure 16, and slide the square along the board. If the blade touches along the entire edge the working edge is at right angles to the working face.

Gauging the width and the thickness is another operation in squaring up the stock. Set the gauge to the desired width and thickness and, working from the working face or the working edge, draw gauge lines to show the desired width and thickness of the finished piece of stock. Plane to the gauge line and test with the try square.

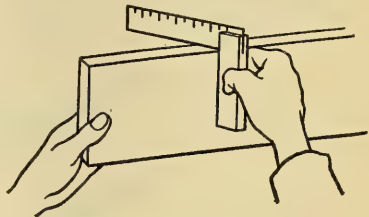


FIG. 16.—Testing the edge.

Measuring for length is another detail of squaring up the stock. Square a sharp pencil line across the working face and the working edge near one end of the board, as shown in figure 17, saw off the end just outside the line, and plane to the line. Measure the length and make a point to indicate its location, square a line through the point, saw to length just outside the line, and plane to the line as before directed.

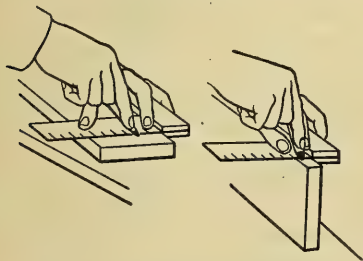


FIG. 17.—Squaring across a board.

Laying out the work has reference to the drawing of lines on a piece of finished stock to indicate the shape it is to be cut. The work should be laid out on the working face and the working edge.

Cutting to lines means to remove the stock to the lines that have been laid out.

Assembling the parts has reference to the fastening of the different pieces together.

USE OF DRAWINGS.

Accompanying most of the exercises are drawings that will aid in the work. The drawings are of three kinds: (1) Perspective drawings, which show the appearance of the finished article; (2) detail drawings, which show the size and the shape of each part; and (3) working drawings, which show the outline of the articles when viewed from the top, the front, and the end. In order to get the three different kinds of drawings clearly in mind refer to figure 18. At the top is shown the perspective drawing of the article, a nail box; below this is the detailed drawing marked sides, bottom, ends, handle; below this is the working drawing marked top view, front view, end view. The outlines in working drawings are what would be seen if one looked squarely down on the top, the front, and the end of the article. In

figure 19 is shown the working drawing of the nail box described and illustrated in Exercise 1, with the front, top, and end views, looked at in the directions of *A*, *B*, and *C*, drawn out and shown in heavy lines to illustrate how they are obtained. In the working drawing of figure 18, these views are shown laid out flat. Solid lines in working

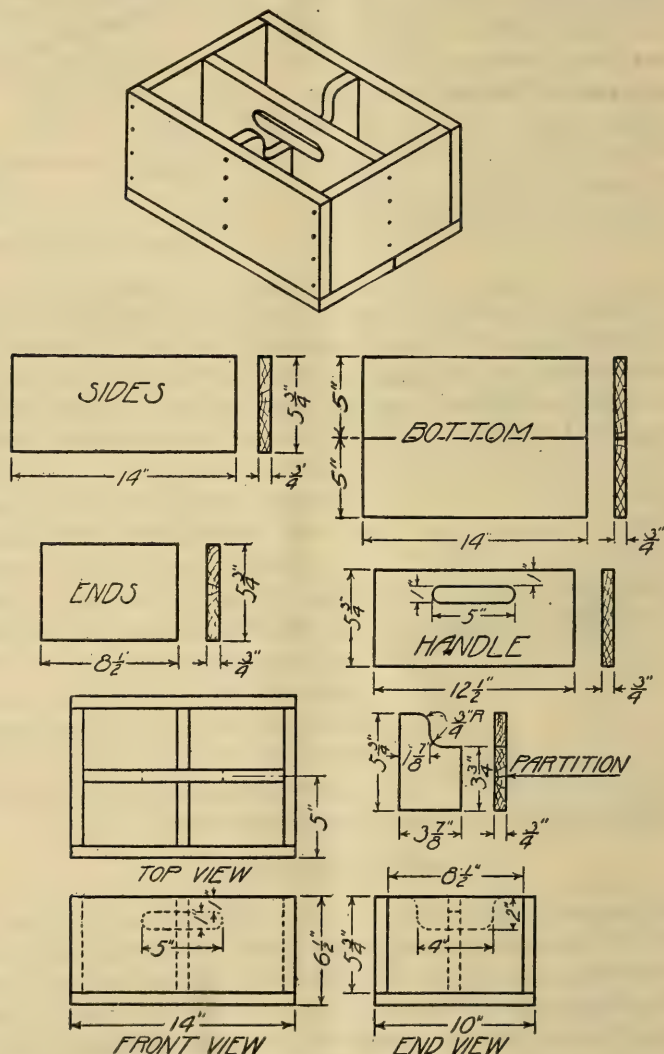


FIG. 18.—Nail box.

drawings show the front edges of the boards; those that can be seen. Dotted lines indicate the edges of boards that can not be seen, because of boards in front of them.

In some of the exercises all three kinds of drawings are shown. In others only the perspective drawing is shown, as it in itself will show how to make the article.

EXERCISE I. NAIL BOX.

A nail box will be needed in connection with the woodworking exercise. The one shown in figure 18 is equipped with two compartments and a handle; it will be found convenient for use in the school and about the farm.

The material required is one-fourth pound of 8-penny finishing nails and a piece of lumber 1 by 6 inches by 8 feet 6 inches. This piece is cut with finished dimensions as follows:

Use.	Number of pieces.	Finished dimensions.
		<i>Inches.</i>
Sides.....	2	by $5\frac{3}{4}$ by 14.
Ends.....	2	by $5\frac{3}{4}$ by $8\frac{1}{2}$.
Bottom.....	2	by 5 by 14.
Handle.....	1	by $5\frac{3}{4}$ by $12\frac{1}{2}$.
Partitions.....	2	by $5\frac{3}{4}$ by $3\frac{3}{4}$.

Cut the pieces called for, allowing $\frac{1}{8}$ inch in width and $\frac{1}{2}$ inch in length on each one; remember that finished dimensions are given above. Plane one of the surfaces of a side smooth and flat to form the working face and test it with a try square. When finished, mark it with a cross (X). Plane one of the edges square with the working face to form the working edge. Test with the try square. When finished, mark it with a check (V) to designate it as the working edge. Gauge for thickness by setting the marking gauge at $\frac{3}{4}$ inch and marking a line from the working face along the edges. Plane the board down to this gauge line and square the side with the working edge. Gauge for width in the same way, measuring from the working edge. Square a pencil line across the working face and working edge near one end, saw the board just outside this line, and plane carefully to the line. Measure the finished length. Finish the other end of the piece in the same way.

Follow the same plan in making the ends and bottom.

To assemble the frame, nail the sides to the end pieces, as shown in the drawing. Plane the edges if necessary to make them fit evenly. Fasten the bottom to the frame. To do this fit the bottom boards to

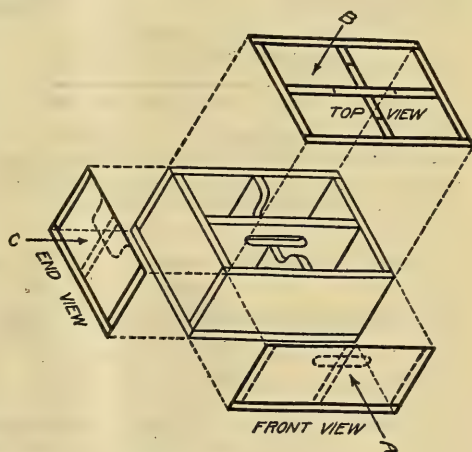


FIG. 19.—Working drawing.

the edges of the frame, test the corners with a try square to make sure the frame is square, and nail the bottom to the frame.

To make the handle, follow the same directions for squaring up the stock as given for the sides, ends, and bottom. Lay out lines for a hole for the handle, as shown by the drawing. This hole is 1 inch wide and 5 inches long and is placed 1 inch from the top and midway

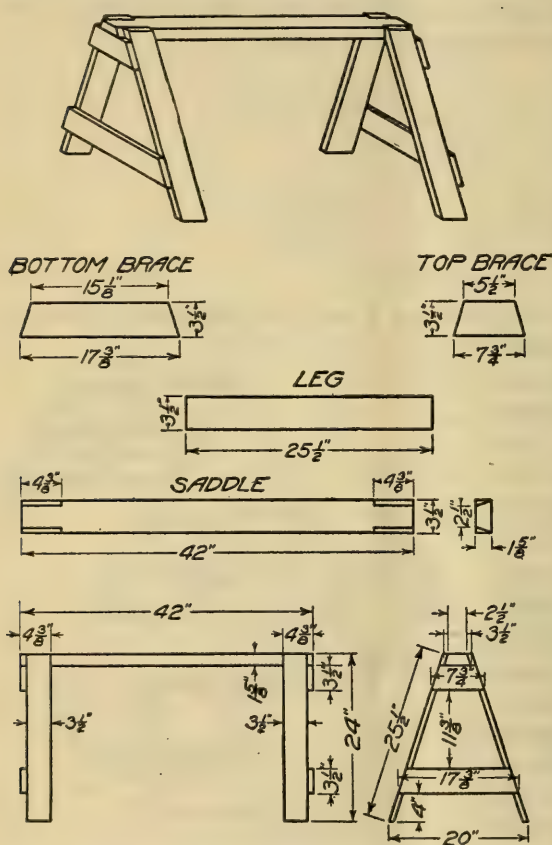


FIG. 20.—Saw horse.

from the ends of the piece. Cut out most of the wood from the hole with a chisel or a brace and bit, and with a knife or chisel carefully smooth to the lines and round the handle. Place the board that forms the handle in the proper place in the box and nail securely.

To make the partition pieces, square up the stock as previously directed for other pieces. Lay out the lines for shaping the top of the partition pieces, as shown in the drawing, either by hand or with a rule and compass. Cut out most of the wood with a saw, and trim with a knife to the line. Place the partition pieces in the

box, as shown in the drawing, and nail in place.

Plane off any unevenness that is found, and the box is finished.

EXERCISE II. SAWHORSE.

A pair of sawhorses will be a convenience in making the wood-working articles. Explicit directions for making a very serviceable pair are given in this exercise. Figure 20 gives the necessary drawings.

The lumber required is one piece hard pine 2 by 4 inches by 5 feet, and two pieces white pine 1 by 4 by 16 inches. The lumber should be what is known as No. 1 common S4S. The abbreviations S4S and

S2S are used to designate lumber surfaced on four sides or two sides, respectively. The hardware required for the sawhorse is $\frac{1}{2}$ pound of 8-penny nails and 1 pound of 10-penny nails.

The bill of stock with finished dimensions and the use of the pieces are as follows:

Use.	Number of pieces.	Finished dimensions.
		<i>Inches.</i>
Saddle.....	1	18 by 3 $\frac{1}{2}$ by 42.
Legs.....	4	7 by 3 $\frac{1}{2}$ by 25 $\frac{1}{2}$.
Top brace.....	2	8 by 3 $\frac{1}{2}$ by 7 $\frac{1}{2}$.
Bottom brace....	2	8 by 3 $\frac{1}{2}$ by 17 $\frac{3}{8}$.

Cut the pieces called for above, allowing $\frac{1}{8}$ inch in width and $\frac{1}{2}$ inch in length for the finishing. It is not necessary to trim the length to the exact measurement.

Next, lay out the saddle and the braces. In laying out the saddle first lay out the shoulder on the ends of the piece, as shown in the drawing. Saw out these shoulders, making them 2 $\frac{1}{2}$ -inches wide at the top, 3 $\frac{1}{2}$ inches at the bottom, and 4 $\frac{3}{8}$ inches long. Smooth up the shoulders with a chisel. Lay out the top brace, making one edge 5 $\frac{1}{2}$ inches long and the other 7 $\frac{3}{4}$ inches long, then lay out the bottom brace, making it 15 $\frac{1}{8}$ inches on one edge and 17 $\frac{3}{8}$ inches on the other. Do not cut off the ends until you assemble the parts.

The next step is to assemble the parts. Nail the legs on the beveled shoulders of the saddle. Have the inside edges of the pieces even with the top of the saddle. The outside corners will be sawed off later.

Use 10-penny nails, driving them partly in. Measure 25 $\frac{1}{2}$ inches from the top end and square a line across the face or the edge of the piece. This is the length of the legs. Tack a strip of board across the bottom of the legs to hold them 20 inches apart. Try the top braces to see if they fit. If they do, saw off the ends and nail them in place, using 8-penny nails. If they do not, square them up to fit. Fit the bottom braces in place in the same manner. Saw off the outside corners of the top of the legs and plane them even with the surface of the saddle. Saw off the lower ends of the legs to make the horse stand firmly on the floor.

EXERCISE III. BIRD HOUSE.

The study of birds is an important phase of agricultural work. Birds are the farmers' friends; they destroy insects and weed seeds. In addition, their presence about the farm home helps to make the surroundings attractive. In order that birds may be provided with shelter, houses for them should be built and placed near the school buildings and homes. Figure 21 shows an attractive and easily constructed bird house.

The material required for this house is one piece of clear white pine $\frac{1}{2}$ by 6 inches by 6 feet, S4S, and a small quantity of 1-inch brads or shingle nails. Often a box can be found that will contain enough $\frac{1}{2}$ -inch pieces to make the house. Take the box apart carefully to avoid splitting the wood.

The bill of stock with finished dimensions and the use of the pieces are as follows:

Use.	Number of pieces.	Finished dimensions.
Bottom.....	1	<i>Inches.</i> $\frac{1}{2}$ by 6 by 10.
Sides.....	2	by 4 by 8.
End.....	2	by $4\frac{1}{2}$ by 6.
Roof.....	1	by 4 by 10.
Roof.....	1	by $4\frac{1}{2}$ by 10.

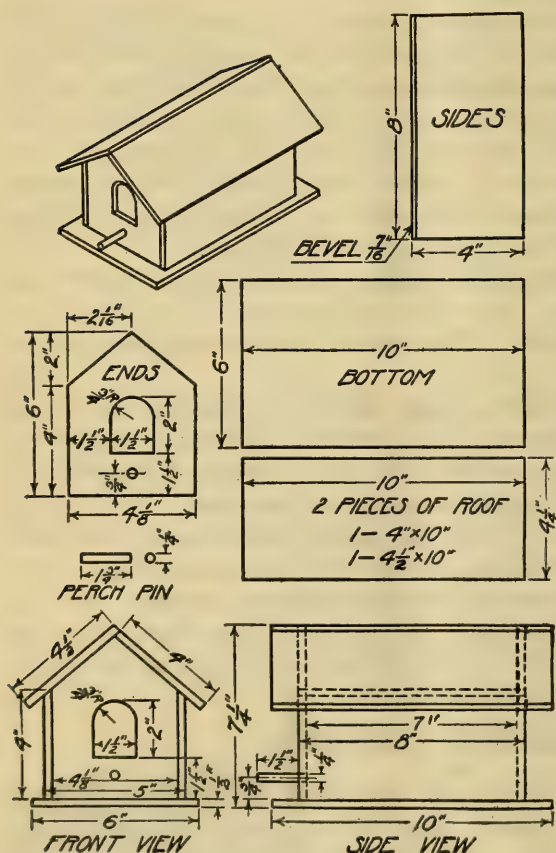


FIG. 21.—Bird house.

Cut and square up the pieces according to the dimensions given above, bevel the sides as shown in the drawings, lay out the door and perch pin hole on one end, as shown in the drawing, bore a $\frac{1}{4}$ -inch hole for the perch pin, bore $\frac{3}{4}$ -inch holes along the inner side of the line laid out for the door, trim to the lines with a knife, lay out and cut the end boards to the proper slant for the roof.

In assembling the parts, nail the sides to the end pieces, using the 1-inch brads or shingle nails, nail bottom to frame, nail on roof boards, whittle a perch pin $\frac{1}{4}$ inch in diameter and 2 inches long and wedge it in

the hole below the door. The bird alights on this pin before entering the door. Paint the bird house; a dark green or a brown is a good color.

NOTE TO TEACHER.—This exercise may be correlated with drawing, language, or geography, as well as agriculture. Have the pupils make a drawing of the house to scale. Let them design and build other types of houses and put them up at home and about the school yard. See list of references given, especially Farmers' Bulletin 609. Language-lesson topics that may be used are: Birds, the Farmers' Friends, Food of Birds, Nature Study and Birds, and Where Birds Migrate. As a geography lesson have the pupils locate the States to which the birds migrate and study the climatic conditions of these States. As lessons in agriculture make studies of the feeding habits of birds and learn what weed seeds and insects are eaten by birds. Learn methods of keeping crows from taking freshly planted corn.

List of U. S. Department of Agriculture publications on birds.

DEPARTMENT BULLETINS.

- No. 107. Birds in Relation to Alfalfa Weevil.
- 128. Distribution and Migration of North American Rails and Their Allies.
- 171. Food of Robins and Bluebirds of United States
- 185. Bird Migration.
- 187. Preliminary Census of Birds of United States.
- 205. Eleven Important Wild Duck Foods.
- 217. Mortality Among Waterfowl Around Great Salt Lake, Utah.
- 280. Food Habits of the Thrushes of the United States.
- 292. Distribution and Migration of North American Gulls and Their Allies.

FARMERS' BULLETINS.

- No. 493. The English Sparrow as a Pest.
- 497. Some Common Game, Aquatic, and Rapacious Birds in Relation to Man.
- 506. Food of Some Well-known Birds of Forest, Farm, and Garden.
- 609. Bird Houses and How to Build Them.
- 628. Game Laws for 1914.
- 621. How to Attract Birds in Northeastern United States.
- 630. Some Common Birds Useful to the Farmer.

YEARBOOK SEPARATE.

- No. 620. American Thrushes Valuable Bird Neighbors.
- 642. Shore Birds and Their Future.

BIOLOGICAL SURVEY CIRCULAR.

- No. 94. Directory of Officials and Organizations Concerned with Protection of Birds and Game. 1913.

EXERCISE IV. SEED GERMINATOR.

In figure 22 is shown a type of seed germinator that is very convenient for testing seed corn. The box is divided into squares by broom wire or cord. Sand or soil is placed in the box, and the kernels are planted in the squares. The rows of squares are numbered one way of the box and lettered the other way. Each square can then be designated by a number and a letter in the same manner as cities and countries are often designated on maps. For example, the upper left hand square is A 1, the upper right hand one, A 10. When corn is to be tested, the ear from which a group of kernels is taken is designated by the same letter and number as the square in which it is planted.

The material required is one piece $\frac{7}{8}$ by 10 inches by 2 feet, one piece $\frac{5}{8}$ by 12 inches by 4 feet, about 32 feet broom wire or cord, and a few 6-penny and 8-penny finishing nails. The stock, with finished dimensions and use of each piece of lumber, are as follows:

Use.	Number of pieces.	Finished dimensions.
Sides.....	2	<i>Inches.</i> $\frac{3}{4}$ by 2 by $20\frac{3}{4}$.
Ends.....	2	by 2 by $19\frac{1}{2}$.
Bottom.....	2	by $9\frac{1}{4}$ by $21\frac{1}{2}$.

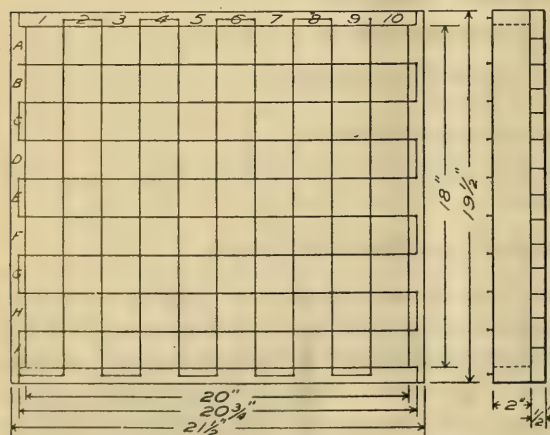
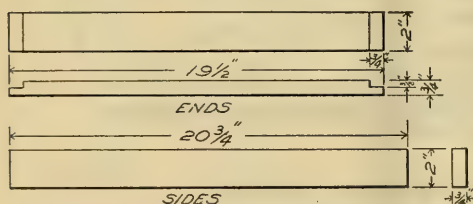
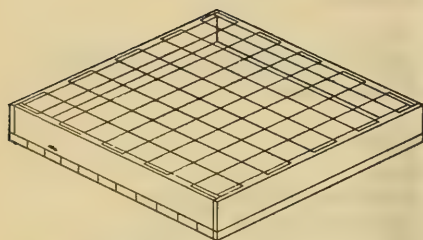


FIG. 22.—Seed germinator.

Rip the $\frac{7}{8}$ by 10 inch by 2 foot board, making four strips, each $2\frac{1}{4}$ inches wide. Cut to lengths of sides and ends and plane to dimensions given above. Saw from the $\frac{5}{8}$ by 12 inch by 4 foot board two pieces, each $21\frac{1}{2}$ inches long and plane to dimensions. Cut notches in ends of end pieces as shown in the drawing.

To assemble, nail the ends to sides. Use 8-penny nails, putting three nails into each cover, two through the end pieces into the side pieces, and one through the side piece into the end piece. This method of nailing makes a good strong corner. Be careful not to split the wood when nailing. Next,

nail the bottom boards in place, using 6-penny nails. Cover the crack between the two bottom boards with a narrow strip of wood to prevent the sand or soil from sifting through the crack.

To provide pegs on which to string the wire to make the squares, drive 6-penny nails 2 inches apart into the top edges of the sides and ends of the box, allowing the heads to project $\frac{1}{4}$ inch above the surface of the wood. Stretch the broom wire or cord around the nails to form the division, as shown in the drawing. Print letters and figures along one end and side, as shown in the drawing. Place sand or soil in the box, and it is ready for use.

A seed germinator similar in construction to the one just described, but without the wires, is often used in seed-corn testing work. Figure 23 shows a perspective drawing of a convenient-sized tester of this kind. The box is $12\frac{1}{2}$ inches wide, $18\frac{1}{2}$ inches long, and 2 inches deep. A box of this size will test 45 ears of corn. The box used in the previous exercise can be used if desired. Half fill the box with sand or sawdust that has been soaked in water at least an hour, pack the material level, and above it stretch a piece

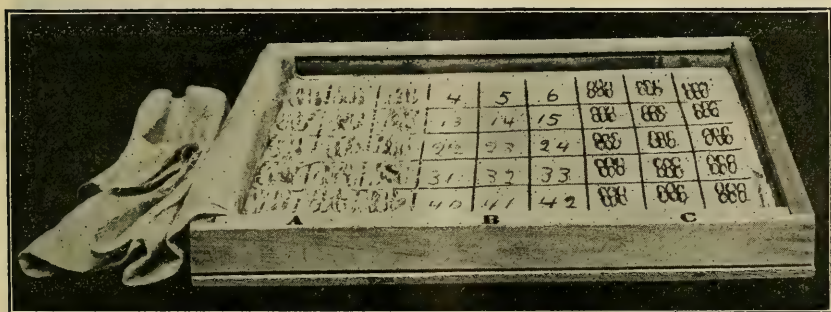


Fig. 23.—Seed germinator.

of muslin that has been ruled into 2-inch squares. Number the squares from 1 to 45, as shown in the illustration. Place the kernels to be tested, germ side up, in the spaces, cover the cloth with another piece of cloth a few inches larger than the box, and place wet sand or sawdust above this cloth. Cover the box with a piece of glass or oilcloth to prevent evaporation of the moisture and set it away in a warm place for a few days. When examining the kernels to see if they have germinated, always roll the top cloth back carefully, otherwise you are likely to get the kernels from the different squares out of place. In the illustration the part marked A shows germinated kernels, that marked B the numbered squares, and that marked C the kernels ready to be tested.

Instead of filling the box with sand or sawdust, the seed bed can be made of heavy canton flannel or similar material. Use two or three thicknesses in the bottom of the box and one or two thicknesses for covering the kernels. A new cloth should be washed before using. It is well to bear in mind that canton flannel comes

27 inches wide. A box of the dimensions given above is just the right width for canton flannel once folded, allowing for shrinkage.

For use, soak the cloth in water and place the half of the cloth, double thickness, which has been marked in squares, in the bottom of the germinating box. Place the kernels from ear No. 1, germ side up, in square No. 1, and so on, as already described. When all of the squares have been filled fold the other end of the cloth carefully over the kernels. If during the sampling the cloths have become dry, sprinkle them well with water.

The principal advantage of this method is that it is almost impossible to injure the corn by the addition of too much water, as is frequently done where tests are made in sand or sawdust.

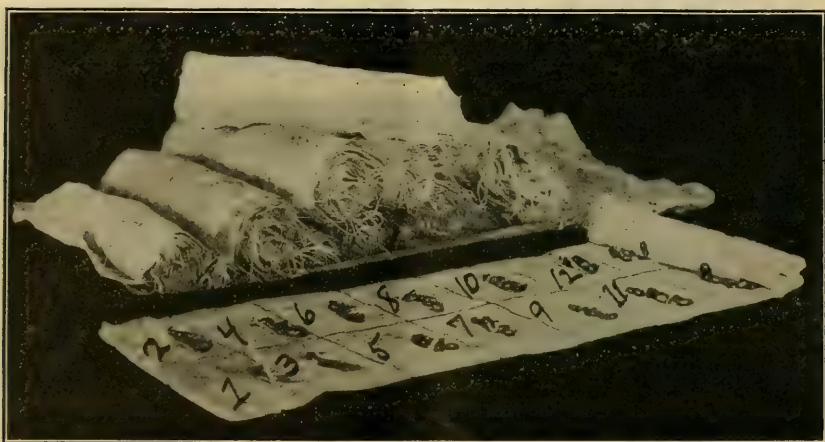


FIG. 24.—Rag-doll seed tester.

In making the box, follow directions (except with regard to dimensions) given for the box shown in figure 22. One should have no difficulty in figuring the amount of material required, cutting the pieces into the proper lengths and assembling them.

In figure 24 is shown what is known as the rag-doll tester.¹ This is one of the cheapest as well as most convenient and accurate methods of testing seed corn. It requires no box.

To make this tester, secure sheeting of a good quality and tear into strips from 8 to 10 inches wide and 3 to 5 feet long. Where these are to be used very much it is well to hem the edges, as otherwise the ravelings sometimes disarrange the kernels in unrolling. Each cloth should then be marked with a heavy pencil; first, lengthwise in the middle, and then crosswise, as shown in the accompanying illustration, making squares about 3 inches wide. Number the squares as shown in the illustration.

Moisten one of these cloths and lay it out on a board of convenient size in front of the ears which are to be tested. Place kernels from each ear in squares numbered to correspond to number of ear. When the cloth has been filled, begin at the upper end with ears Nos. 1 and 2, etc., and roll the cloth up. Since the cloth is moistened,

¹ The description and illustration are based on Iowa Agricultural Experiment Station Bulletin 135.

the kernels will not push out of place. If a small irregular-shaped piece of wood or some other substance is used as a core in rolling, a more uniform germination may be secured. When the rolling of the cloth has been finished, tie a string rather loosely about the middle of the roll, or, better still, use a rubber band, and number this roll No. 1. Then proceed with roll No. 2 in the same way. As many rolls may be used as are necessary to contain the corn which one has to test. From 20 to 50 ears may be tested in each roll, depending upon the length.

After the rolls have been filled they should be placed in a bucket of water, where they may remain for from 2 to 18 hours, depending upon the preference of the operator. At the end of this time pour off the water and turn the bucket upside down over the rolls—or a common dry-goods box may be used for this purpose. A couple of small pieces of wood should preferably be laid under the rolls, and one edge of the pail should be lifted from $\frac{1}{2}$ to 1 inch in order to give sufficient ventilation. Some have left the pail in an upright position, placing a few sticks or corncobs in the bottom of the pail to insure proper drainage, and then packing a moist, coarse cloth over the rolls to prevent excessive drying. At the end of five days the kernels should be ready to read.

Depending upon the arrangement of the ears, select, first, either roll No. 1 or the last roll filled. This cloth will be unrolled in front of the ears which are represented. Examine all the kernels carefully. In all cases in which all six kernels are not strong in germination the ear should be thrown away.

NOTE TO TEACHER.—One of the very best lines of agricultural work for schools is the testing of seed corn. It is a means of getting not only the pupils, but also the parents interested in agriculture. Often the latter is a very important consideration in the success of the work. It pays to test seed corn, for it is often the means of preventing a poor stand or the replanting of a crop.

As correlations with the agricultural work and the manual-training exercise, have the pupils compute the value of the lumber in a box, the value of the time to make it, the cost in time of testing, say, 100 ears of corn, and use the figures obtained in formulating problems to determine whether or not the testing of seed corn is an expensive practice.

EXERCISE V. SEED-CORN DRYING RACK.

Seed corn should be stored in a cool, dry place, and the ears should be kept apart, in order that air can circulate freely about them. A very convenient and easily constructed rack is shown in figure 25. To make this rack, rip a piece of 2 by 4 inch in strips 2 by 2 inches

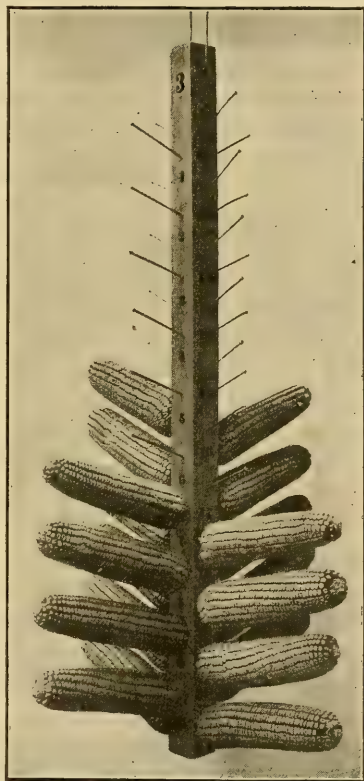


FIG. 25.—Seed-corn drying rack.

and 6 feet long. Exact measurements, however, are not necessary. Smooth up the pieces, bore a half-inch hole near one end, and loop a rope through it. This rope is hung over a nail or hook in the ceiling of the storage room when the rack is in use. Drive 10 finishing nails on each side of the piece, spacing them $5\frac{1}{2}$ inches apart. Number the nails from 1 to 40 (there will be 10 on each side of the piece). This may be done with a pencil, or figures may be cut from a calendar and the numbers pasted on the wood. When the rack is to be used, the butts of the corncobs are stuck on the nails, as shown in the illustration.

NOTE TO TEACHER.—The pupils should be impressed with the necessity of storing seed corn properly. The making of these racks by the pupils will create an interest in this phase of the work. In Farmers' Bulletins other devices for drying seed corn are given.

EXERCISE VI. SEED SAMPLE CASE.

Collections of farm seeds, weed seeds, and farm seeds containing weed seeds as impurities should be made in the schools and kept for

use in studying crops, weeds, and seed adulterations. To care for such collections properly, a case to hold the seeds is necessary. Figure 26 shows a convenient case in which small bottles of seeds may be stored. The bottles are straight sided, $\frac{1}{2}$ inch in diameter and $2\frac{1}{2}$ inches deep; they can be purchased at drug stores for about 10 cents a dozen. Those with screw tops are more convenient than those with corks.

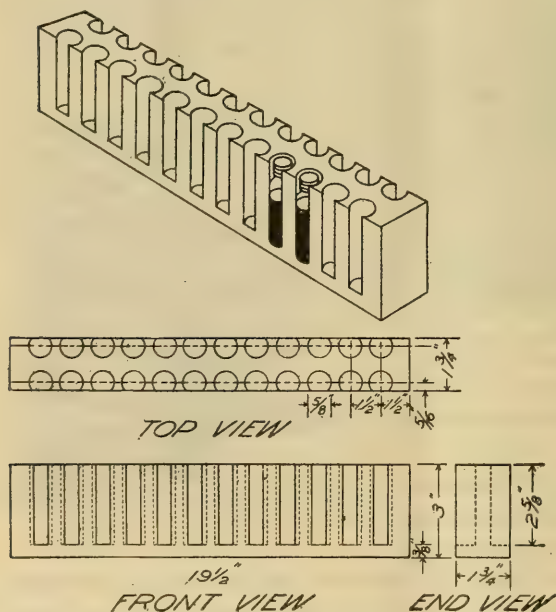


FIG. 26.—Seed case.

The material required for making the case is a piece of white pine 2 by 4 by 20 inches. Finish the piece to the dimensions shown in the drawing, $1\frac{3}{4}$ by 3 by $19\frac{1}{2}$ inches. Gauge two lines $\frac{5}{16}$ inch from both sides on one edge. On these gauge lines lay off centers for holes $1\frac{1}{2}$ inches apart, beginning $1\frac{1}{2}$ inches from one end. Place the piece, with a strip of scrap board against it on one side, in a vise, and with a $\frac{5}{8}$ -inch bit and brace bore holes $2\frac{5}{8}$ inches deep on the centers that have been laid off. The scrap board prevents the lumber from

slivering. Bore the holes straight into the wood. See directions on page 5. To aid you in boring the holes to the exact depth desired, bore a $\frac{3}{8}$ -inch hole lengthwise through a piece of scrap lumber $1\frac{1}{2}$ by $1\frac{1}{2}$ by 4 inches, and slip this on the shank of the bit to form a collar; the bit should extend $2\frac{3}{8}$ inches beyond the collar. Bore a trial hole in a piece of scrap lumber with this collar on the bit; if the hole is too shallow, cut off the end of the collar to get the correct length; if the hole is too deep, make another collar. After the holes are bored, trim the edges along the sides of the piece until each opening is $\frac{3}{8}$ inch wide. Paint or stain the case; this will improve its appearance as well as preserve the wood.

NOTE TO TEACHER.—Collections of seeds are very useful aids in teaching agriculture. A pupil will get a much better idea from examining the seeds themselves than by reading about them. If you are to do efficient work in crop studies, you must have the seeds and, moreover, they must be arranged in some kind of order and be of convenient access. The seed sample case solves the question of a place in which to put the seeds. For an extended discussion of this subject see Farmers' Bulletin 586.

Descriptions of weed seeds and methods of eradication are good topics for written lessons. Many weeds have been introduced into the United States from foreign countries; the Russian thistle, for example. A study of the climate and plants of these countries will add to the interest of the geography lessons. Enlarged drawings of seeds as they may be seen under a lens are useful, not only for their agricultural value, but for the drawing lessons as well.

EXERCISE VII. HOTBED AND COLD FRAME.

A hotbed is a bed of fertile soil surrounded by a glass-covered frame, usually of wood, and heated artificially. As a rule fresh stable manure is placed in the bottom of a hotbed as the source of heat. A cold frame is a box-like frame covered with glass or muslin. These frames are similar to hotbeds except that no heat is supplied artificially. The sun's rays through the glass are depended upon as the source of heat. The principal use of hotbeds is for the production of plants for early setting. Cold frames are used primarily to harden off plants that have been started in a hotbed. They are used also to mature crops earlier in the season than if they were grown in the field and to lengthen the growing season of certain crops that do not normally mature in a given locality. Temporary cold frames are sometimes built over partly grown crops in the field; lettuce, for example, for the purpose of protecting the plants during the cold weather of early spring and hastening their growth. Hotbeds and cold frames should be set in well-drained soil and should slant toward the south.

The most common sash used for hotbeds and cold frames is 3 feet wide and 6 feet long, with the side pieces, known to gardeners as stiles, extending 2 inches beyond the ends. These projections

serve to strengthen the corner joints, and they are used as handles when removing the sash from the frame. The sash when in use is laid on the frame, the weight holding it in place.

Figure 27 shows a simple one-sash cold frame that can be used also as a hotbed by placing it over an excavation in which has been placed 2 inches of ashes or stone, 3 or 4 inches of straw, and a layer of fresh horse manure. The thickness of the manure will vary from 6 to 24 inches,

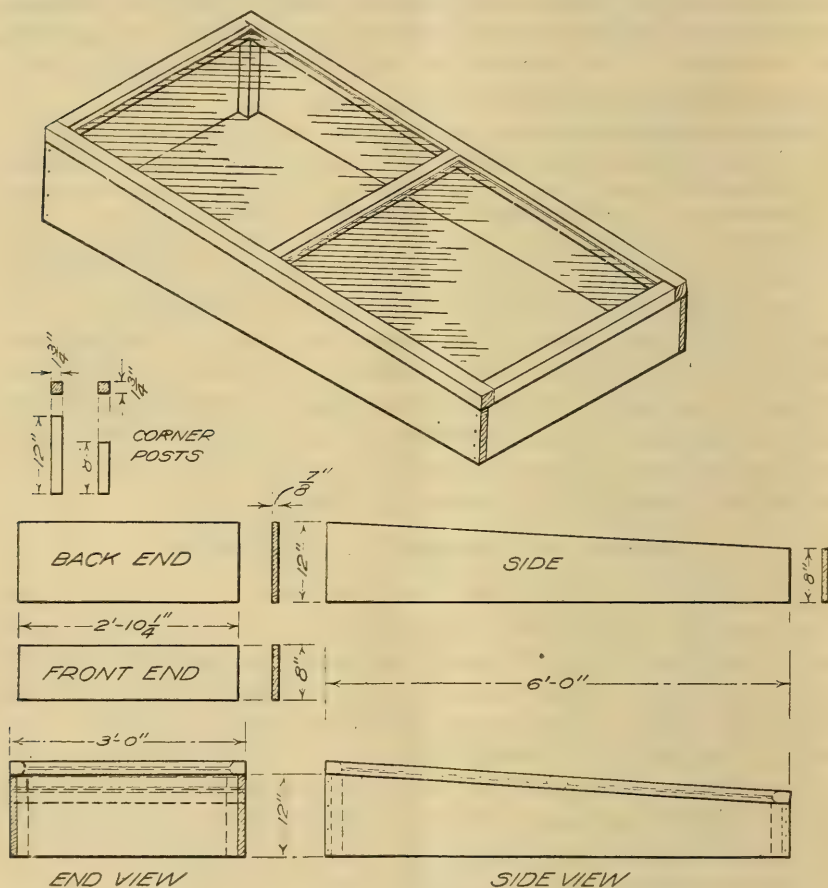


FIG. 27.—Cold frame.

depending on the climate and the season. Above the manure, 2 or 3 inches of straw and 5 or 6 inches of mellow soil are placed. When the frame is used as a cold frame it is placed directly over the soil in which the vegetables are to be grown; this soil should be put into a good state of tilth before the frame is built.

The material required for the frame shown in figure 27 is one piece of board $\frac{7}{8}$ by 12 inches by 15 feet, one piece $\frac{7}{8}$ by 8 inches by 3 feet, one piece 2 by 4 by 21 inches (if a piece of 2 by 4 inch dressed lum-

ber is used it will probably measure $1\frac{5}{8}$ by $3\frac{1}{2}$ inches), one glass sash 3 by 6 feet, and a quantity of 8-penny common nails.

The bill of stock with finished dimensions and uses of the pieces is given below:

Uses.	Number of pieces.	Finished dimensions.
Sides.....	2	$\frac{7}{8}$ by 12 inches at one end and 8 inches at the other by 6 feet.
Back.....	1	$\frac{7}{8}$ by 12 inches by 2 feet $10\frac{1}{4}$ inches.
Front.....	1	$\frac{7}{8}$ by 8 inches by 2 feet $10\frac{1}{4}$ inches.
Posts at back....	2	$1\frac{1}{4}$ by $1\frac{3}{4}$ by 12 inches.
Posts at front....	2	$1\frac{1}{4}$ by $1\frac{3}{4}$ by 8 inches.

Cut from the $\frac{7}{8}$ by 12 inch by 15 foot board two pieces 6 feet long and one piece 3 feet long to form the sides and back pieces. Taper the side pins by laying off a slanting line on the board with one end 12 inches from the base and the other 8 inches, and saw and plane to this line. If the board lacks a little in width, say, if only $11\frac{3}{4}$ inches wide, use this dimension instead of the 12 inch. The back, too, will be the same length. Square up the 3-foot board cut from the large board to the dimension given for the back. From the 3-foot board (8 inches wide) given in the list of material, square up the piece for the front. Rip the 21-inch piece of 2 by 4 inches into two pieces and saw each in two to form the posts.

To assemble, place the corner posts on the inside ends of the side boards and nail with 8-penny common nails. Place end boards in position even with the side boards and nail securely. Saw posts flush with top. Lay the sash on the frame, and the cold frame is ready for use.

NOTE TO TEACHER.—Hotbeds and cold frames can be used very effectively in school and home garden work. They lengthen the growing season so much that several months more gardening work can be done by the pupils. In northern sections green plants can be grown in hotbeds as late as December, and in many southern sections cold frames make gardening possible all winter.

For further suggestions concerning the use of hotbeds and cold frames see Farmers' Bulletins 255, The Home Vegetable Garden; 642, Tomato Growing in the South; 647, The Home Vegetable Garden in the South; 460, Frames as Factors in Truck Growing.

School and Home Garden Circulars 1 to 10, published by the Bureau of Education, Department of the Interior, contain information about hotbeds and cold frames. These may be secured by writing to the Commissioner of Education, Department of the Interior, Washington, D. C.

EXERCISE VIII. FLATS.

Vegetable growers have much use for small wooden trays known as flats. They are especially useful in transplanting plants from the hotbed to the cold frame. In one method of transplanting the

gardener removes a quantity of plants from the hotbed to a warm room and transplants them to the flats. The flats with the newly planted seedlings in them are then placed in the cold frames. Later they may be transplanted to the soil of the cold frame or to the field direct.

Flats vary considerably in size. Perhaps the most common sizes are 20 to 24 inches in length, and 15 to 16 inches in width; $2\frac{1}{2}$ inches is the usual depth. The ends are in most cases made of $\frac{1}{2}$ -inch material and the sides and bottom of $\frac{1}{4}$ -inch material. Cracks $\frac{1}{8}$ inch in width are left in the bottom to provide for drainage.



FIG. 28.—Flat.

Figure 28 shows a flat 24 by 16 by $2\frac{1}{2}$ inches inside measurement. Make several flats of this or any other convenient size, using $\frac{1}{2}$ -inch material for the ends and $\frac{1}{4}$ -inch material for the sides and bottom. Leave $\frac{1}{8}$ -inch cracks in the bottom. From the experience you have had in previous exercises you will be able to construct them without having the detailed instructions before you. Make out a bill of materials, a bill of stock, cut the pieces, square them up, and assemble them.

Inexpensive flats are often made by gardeners from soap or other similar boxes by sawing the box into sections about $2\frac{1}{2}$ inches in depth and nailing strips on these sections to form bottoms for the flats. Figure 29 shows how to mark out the box for sawing it into sections. Get a box and some pieces of $\frac{1}{4}$ -inch strips for bottoms and make a few flats in this way. If the box has a bottom and a cover on it, you can use these for the bottoms of two of the flats.

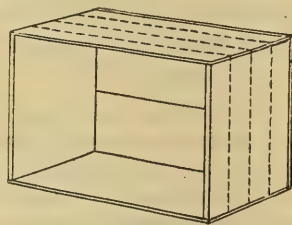


FIG. 29.—Method of marking box for sawing into flats.

NOTE TO TEACHER.—Flats should be found in every school where agriculture is taught. They may be used in connection with a hotbed and cold frame as described previously or be placed in sunny windows in the schoolhouse. Plants for study during the winter or for transplanting to the garden to secure early crops are often grown successfully in flats in schoolhouses. A shelf wide enough for the flats is built on a level with the window sill.

EXERCISE IX. FORCING BOX.

A very practical piece of equipment for use in forcing the growth of rhubarb and asparagus in the early spring is shown in figure 30. One of these boxes is placed over a clump of rhubarb or asparagus late in the fall or early in the spring, and barnyard manure is filled in around the box. The heat from the manure and from the sun's rays through the glass cover warms the soil under the box, and as a result the plants start to grow earlier. Often plants can be forced to pro-

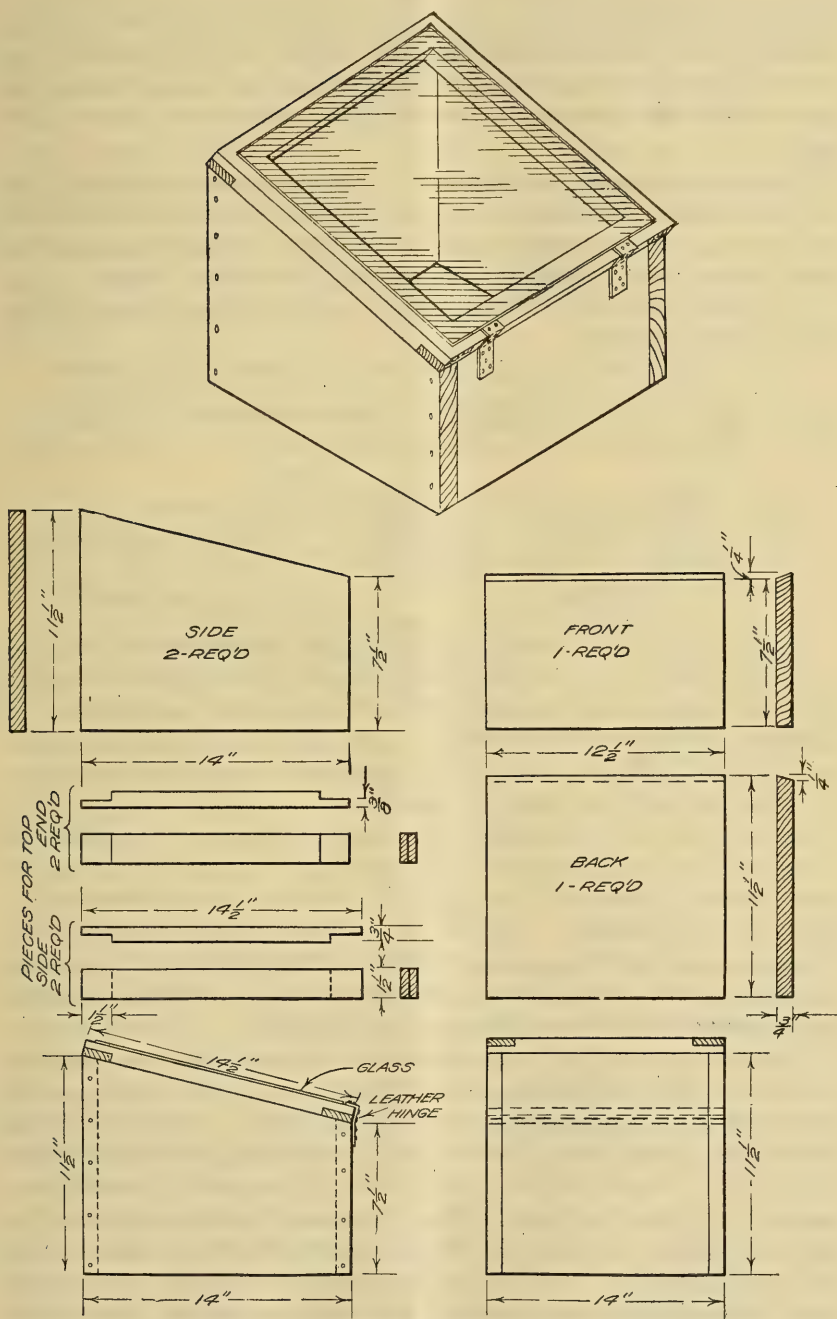


FIG. 30.—Forcing box.

duce a crop three or four weeks earlier than usual. Some gardeners place a half-barrel or a keg over the plants and cover it with manure to force them in the spring, but the forcing box is preferable on account of the heat that comes through the glass; also, because the plants—rhubarb especially—lack the green color when grown in the dark.

The material needed is one piece of board, cypress preferred, $\frac{7}{8}$ by 12 by 42 inches, one piece $\frac{7}{8}$ by 8 by 28 inches, one piece of glass 13 by 13 inches, a few 8-penny nails, 1-inch brads, and 10-ounce carpet tacks, and a piece of leather large enough for the two hinges.

The stock with finished dimensions and the use of each of the pieces are as follows:

Use.	Number of pieces.	Finished dimensions.
		<i>Inches.</i>
Back.....	1	by $11\frac{1}{2}$ by $12\frac{1}{2}$.
Side.....	2	by $11\frac{1}{2}$ at one end and $7\frac{1}{2}$ at the other end by 14 long.
Front.....	1	by $7\frac{3}{4}$ by $12\frac{1}{2}$.
Cover.....	2	by $1\frac{1}{2}$ by 14.
Do.....	2	by $1\frac{1}{2}$ by $14\frac{1}{2}$.

Cut the $\frac{7}{8}$ by 12 by 42 inch piece into three pieces, two of them $14\frac{1}{2}$ inches and the other 13 inches long. Square these up to dimensions given for back and side pieces. Bevel the back piece as shown in the drawing. To make the top edge of a side piece slanting, draw a line on the board with one end $11\frac{1}{2}$ inches from the base and the other $7\frac{1}{2}$ inches and saw and plane to this line.

Cut the $\frac{7}{8}$ by 8 by 28 inch piece of material into two lengths, one 13 inches long and the other 15 inches long. Square up the first of these pieces to form the front piece of the box. Bevel this piece as shown in the drawing. Rip the other piece into four strips, each $1\frac{7}{8}$ inches wide, and square up to form the four pieces of the cover. Lay off and cut the ends of these pieces to form the half-lap joints at the corners of the cover as shown in the drawing.

With the pieces all cut and squared up, the next step is to assemble the parts. Nail the front and back pieces to the side pieces, using 8-penny nails. Place the four strips of the cover in position and nail the half-lap joints, using 1-inch brads and bending them over on the under side. Fasten the cover to the box by means of the pieces of leather that form the hinges. Place the glass in position on the cover and drive carpet tacks into the wood along the front and sides to hold the glass in place. Also, drive two or three tacks along the back edge; these tacks can be removed and the glass slid out when ventilation is necessary or the plants are to be gathered.

NOTE TO TEACHER.—These forcing boxes can be made useful aids in teaching agriculture. If you have no rhubarb or asparagus in the school garden, undoubtedly you can get permission to use a few clumps at some near-by farm. The pupils will be interested in observing the difference between the forced and unforced plants, and, in addition, it will show them the necessity of warmth in plant growth.

The making of the boxes and their use in a garden will suggest good ideas for written lessons. As problems in arithmetic, have the pupils keep records of the sale prices of forced and unforced rhubarb and asparagus and compare the results, taking into account the cost of the boxes. As the boxes should last, say, five years, they should be figured at one-fifth of the actual cost.

EXERCISE X. SORTING TABLE FOR VEGETABLES AND FRUITS.

In figure 31 is shown a sorting table for use when packing vegetables and fruits. It is especially useful for tomatoes and apples. The

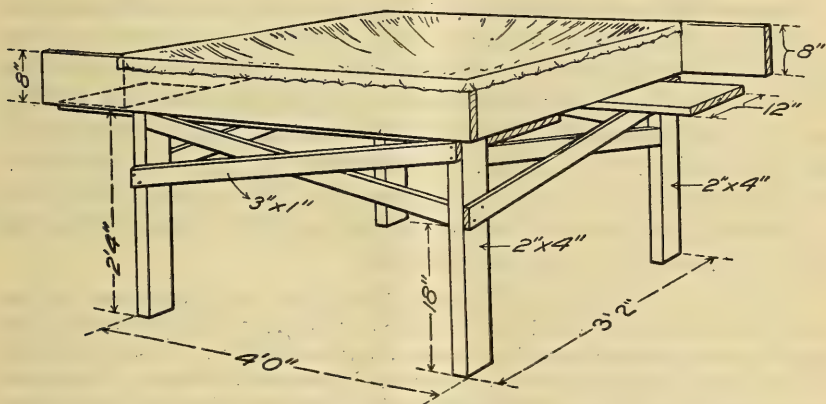


FIG. 31.—Sorting table.

table is 3 feet high, 3 feet 2 inches wide, and 4 feet long and will accommodate two packers. The top is made of burlap or canvas stretched loosely on the frame; this provides a yielding surface that will not bruise the product to be packed. The baskets or other containers to be filled are placed on rests made by a board extending across the bottom of the frame. Two of the side boards extend out a foot to provide a rest against which a box or other flat container can be leaned, if such a type is used.

The lumber required is one piece of 1 by 8 inches by 16 feet, one piece 1 by 12 inches by 10 feet, two pieces 1 foot by 3 inches by 10 feet, two pieces 1 foot by 3 inches by 8 feet, and one piece 2 by 4 inches by 12 feet. The other material required is two pieces of burlap or canvas, each 4 by 5 feet, 14 feet of old rubber hose, and a quantity of 8 and 10 penny nails.

The bill of stock is as follows:

Use.	Number of pieces.	Dimensions.
		<i>Inches. Feet.</i>
Frame.....	2	1 by 8 by 5.
Frame.....	2	1 by 8 by 3.
Rest boards.....	2	1 by 12 by 5.
Braces.....	4	1 by 3 by 5.
Braces.....	4	1 by 3 by 4.
Legs.....	4	2 by 4 by 3.

Saw the 16-foot board into four pieces to form the frame, the 10-foot board into two pieces to form the rest boards, the 2 by 4 inch into four pieces to form the legs, the two 10-foot strips into four pieces for braces that will run the long way of the table, and the two 8-foot strips into four pieces for braces that will run the short way of the table.

To assemble, nail the frame together, turn it upside down and nail the legs in place, using 10-penny nails, nail the rest boards in place, turn the table right side up and nail braces in place along the sides, using 8-penny nails, saw off the ends of the braces flush with the leg, nail the two thicknesses of burlap or canvas on the top of the frame, and nail the piece of rubber hose around the edge of the frame. This rubber hose gets rid of the sharp edge. If no hose is available, nail several thicknesses of burlap on the edge of the frame before the two thicknesses of burlap are fastened.

NOTE TO TEACHER.—As an aid in teaching agriculture, have one or two of these sorting tables made and carried to an orchard where apples are to be harvested. The pupils can be given some practical lessons in sorting the fruit. Be sure they learn that the burlap or canvas is to aid in protecting the fruit from bruising. After sorting a few baskets of fruit, compare them with an unsorted lot. The better appearance of the sorted fruit will often be a surprise to them. Too much fruit goes to market carelessly sorted.

These tables are useful in tomato-club work. A carefully sorted lot of tomatoes makes a much better appearance than a vine-run lot.

EXERCISE XI. PLANTING BOARD.

The usual method followed when laying out an orchard for planting is to set a stake at the point where each tree is to be located; but as this stake must be removed when the hole for the tree is dug, a planting board is often employed to get each tree in its proper place. In figure 32 is shown a drawing of a planting board, with the dimensions given. When using a planting board, the 2 by 2 inch notch is placed over the stake that indicates where the tree is to stand, and two stakes are driven into the ground at the points of the notches at both ends of the board. The board is then removed and the hole dug. When the tree is to be set, the planting board

is placed over the hole with the two notched ends over the stakes in the same position as before. The tree is placed in the hole at the position of the 2 by 2 inch notch in the board. Thus the tree stands in the same place as the stake did before the hole was dug.

To make a planting board, get a piece of 1 inch by 6 inch by 3 foot 6 inch lumber and saw out the notches as shown in the drawing.

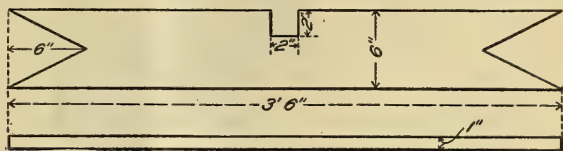


FIG. 32.—Planting board.

NOTE TO TEACHER.—

The planting of an orchard is such an important part

of fruit growing that some instruction about it should be given in the schools. An important item of the work is to get the trees in straight lines. The planting board described in this exercise is a means whereby this can be accomplished, and for this reason it is well to have each pupil make one.

EXERCISE XII. STAMPER FOR CRUSHING LUMPS OF FERTILIZER.

In the home mixing of fertilizer one of the tasks necessary in preparing the material is to crush the lumps of certain of the ingredients. A very handy tool for this work, and one easily constructed by the pupils, is the homemade stamper shown in figure 33. To make the stamper, cut off 18 inches from a piece of 6 by 6 inch hemlock, smooth up a 3-foot piece of hickory or other tough wood that is about the size of a pick handle, bore a hole in the end of the hemlock block, and wedge in the handle. Often an old pick or sledge handle can be used for the purpose.

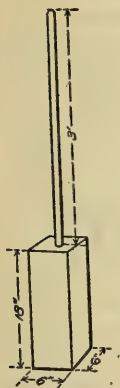


FIG. 33.—Home-made stamper for crushing fertilizer.

NOTE TO TEACHER.—The home mixing of fertilizer is a subject that should be taught in every country school. This simple exercise can be made the means of interesting your pupils, and also their parents, in the work. One of the arguments often given against the home mixing of fertilizer is the fact that some of the ingredients are likely to be lumpy. If you can get the pupils to mix a batch of fertilizer and use this stamper to crush the lumps, they will learn that the lumpiness of the ingredients usually is not a formidable objection to home mixing.

EXERCISE XIII. FEED HOPPER FOR POULTRY.

A very convenient hopper for grains and ground meals for use in poultry houses is shown in figure 34. It is easily constructed, inexpensive, and where used has given satisfaction.

The material required is one piece of cypress $\frac{3}{4}$ by 10 inches by 8 feet, two small hinges, 1 dozen $\frac{7}{8}$ -inch screws, and a quantity of 6-penny finishing nails.

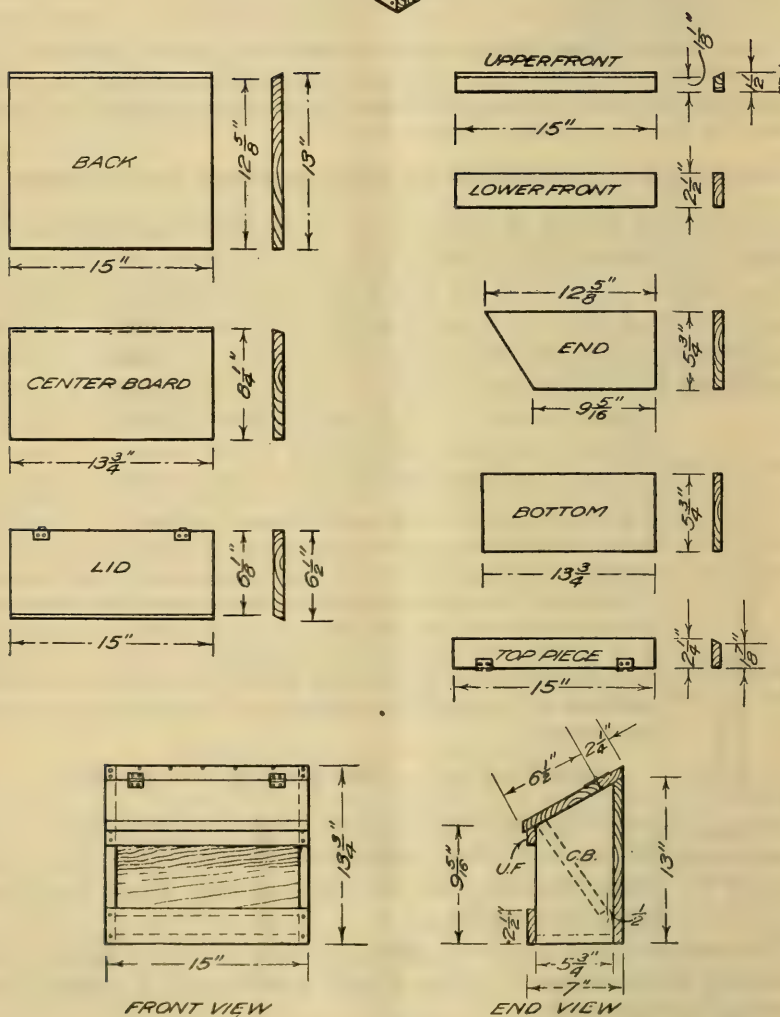
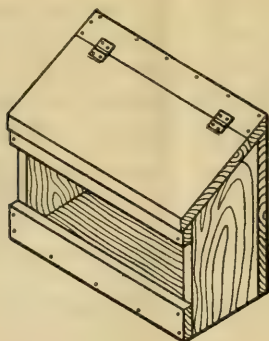


FIG. 34.—Feed hopper.

The bill of stock is as follows:

Use.	Number of pieces.	Finished dimensions.
		<i>Inches.</i>
Back.....	1	by 13 by 15 (this is made of 2 pieces).
Bottom.....	1	by 13 $\frac{3}{4}$ by 5 $\frac{3}{4}$.
Centerboard.....	1	by 8 $\frac{1}{2}$ by 13 $\frac{3}{4}$.
Ends.....	2	by 5 $\frac{1}{2}$ by 12 $\frac{3}{8}$.
Lid.....	1	by 6 $\frac{1}{2}$ by 15.
Upper part of front.....	1	by 1 $\frac{1}{2}$ by 15.
Lower part of front.....	1	by 2 $\frac{3}{4}$ by 15.
Top piece.....	1	by 2 $\frac{1}{4}$ by 15.

Cut from the 8-foot board one piece 15 $\frac{1}{8}$ inches; from this piece rip off 5 $\frac{7}{8}$ inches and square up to make the bottom piece, and square up the other piece to be 3 $\frac{1}{2}$ inches wide for one of the pieces of the back. Cut another piece 15 $\frac{1}{8}$ inches long from the original board and square it up to 9 $\frac{1}{2}$ inches in width to form the second piece of the back. Bevel the top of the back, as indicated in the drawing. Cut a piece 13 $\frac{7}{8}$ inches in length from the original board and square it up to the dimensions required for the centerboard. Rip a strip 2 $\frac{3}{4}$ inches in width from what remains of the original board and cut and square up to form the upper and lower parts of the front, and the top piece. Bevel the pieces that form the upper part of the front and the top piece, as shown in the drawing. From the remaining part of the original board cut and square up the end pieces and lid. Bevel the lower end of the lid piece, as shown in the drawing.

To assemble, nail the end pieces to the bottom, nail the centerboard to the end pieces, carefully adjusting the centerboard to the correct position, as shown in the drawing, nail the upper and the lower pieces of the front to the end boards, nail the back to the end boards, placing the narrow piece above the wider piece, nail the top piece to the top of the end boards and the back, place the lid in position, and screw the hinges in place.

NOTE TO TEACHER.—Poultry is found on every farm, and this fact makes poultry husbandry an especially desirable subject to be taught in the schools. In order that the teaching may be profitable, it is necessary that the pupils take care of a few fowls, either at the school or at home as a home project or home practicum. The making of convenient appliances as described in this and some of the subsequent exercises will add much interest to the work.

EXERCISE XIV. TRAP NEST.

A trap nest is a laying nest so arranged that after a hen enters it she is confined until released by the attendant. By using such nests the egg record of each of the hens of the flock may be determined. A very convenient type of trap nest, the one used at the Government poultry farm, is described with full directions for making in Farmers' Bulletin 682. In working out this exercise, send to the Department of Agriculture for this bulletin and follow the directions given.

EXERCISE XV. BROOD COOP.

In figure 35 are shown detailed drawings of a brood coop described in Farmers' Bulletin 574. By following directions carefully you should be able to build one of these coops. The bill of material is as follows:

- 1 piece hemlock, 2 by 3 inches by 5 feet.
- 3 pieces white pine or spruce, 1 by 2 inches by 10 feet.
- 1 piece white pine or spruce, 1 by 3 inches by 3 feet.
- 2 pieces $\frac{1}{2}$ by 2 inch stop, 30 inches long.
- 34 square feet $\frac{1}{4}$ -inch matched yellow-pine flooring.
- 1 pair 2 by 2 inch steel or japanned butts.
- 3 pounds 8-penny common nails.
- 1 piece wire netting, $\frac{1}{2}$ -inch mesh, 10 by 30 inches.
- 1 piece wire netting, $\frac{1}{2}$ -inch mesh, 9 by 15 inches.
- 2 pieces wire netting, $\frac{1}{2}$ -inch mesh, 4 by 4 inches.
- A few staples.

The material should be examined to see that it is what was ordered; then the pieces should be laid out to cut with least waste, laying out first the longest pieces required.

To build the bottom of the coop, cut the 2 by 3 inch by 5 foot hemlock into two 30-inch pieces. Cut enough of the matched flooring into 18 $\frac{1}{4}$ -inch lengths to cover the length of 28 $\frac{1}{4}$ inches. Nail the pieces of flooring to the 2 by 3 inch strips, nailing on the 3-inch face with 8-penny common nails. As shown in the sketch, the flooring is to be kept $\frac{7}{8}$ inch back from the face and the ends of the 2 by 3 inch strips to allow for thickness of ends and sides.

To build the back, cut from the 1 by 2 inch white pine or spruce two pieces 28 $\frac{1}{4}$ inches long. Next, cut enough pieces of flooring 16 inches long to cover 30 inches. Nail the flooring to the 1 by 2 inch strips as illustrated, observing that the strips are kept back at each end $\frac{7}{8}$ inch to allow for the sides to fit in, and the bottom strip up $\frac{7}{8}$ inch to fit over the coop bottom.

The end sections are made in pairs—right and left. From the 1 by 2 inch strips cut one piece 16 $\frac{1}{2}$ inches and one about 21 inches long. Cut enough pieces of flooring 26 inches long to cover 19 inches. Place the bottom strip $\frac{7}{8}$ inch up from the bottom of your flooring and $\frac{3}{8}$ inch in from edge of flooring, then measure 24 inches to the long point of the end from bottom and 16 inches to short point of end and place top strip at these points. Having nailed the flooring to the strips, cut the flooring along the top edge of the top strip, forming the slope of the roof. Then cut the top strip back $\frac{7}{8}$ inch on each end from the edge of the flooring. With compasses describe a circle as shown in the figure, and with brace and bit and compass-saw cut out the circle described. On the inside of the coop nail a piece of wire screen over this hole with wire staples.

To build the front section, cut from the 1 by 2 inch strips two pieces $28\frac{1}{2}$ inches and three pieces 15 inches long. Cut enough pieces of flooring 15 inches long to cover 18 inches. Cut a piece of wire netting 10 by 30 inches and nail to nailing strip. Then nail flooring and slats to nailing strips as illustrated, keeping top nailer $\frac{1}{2}$ inch

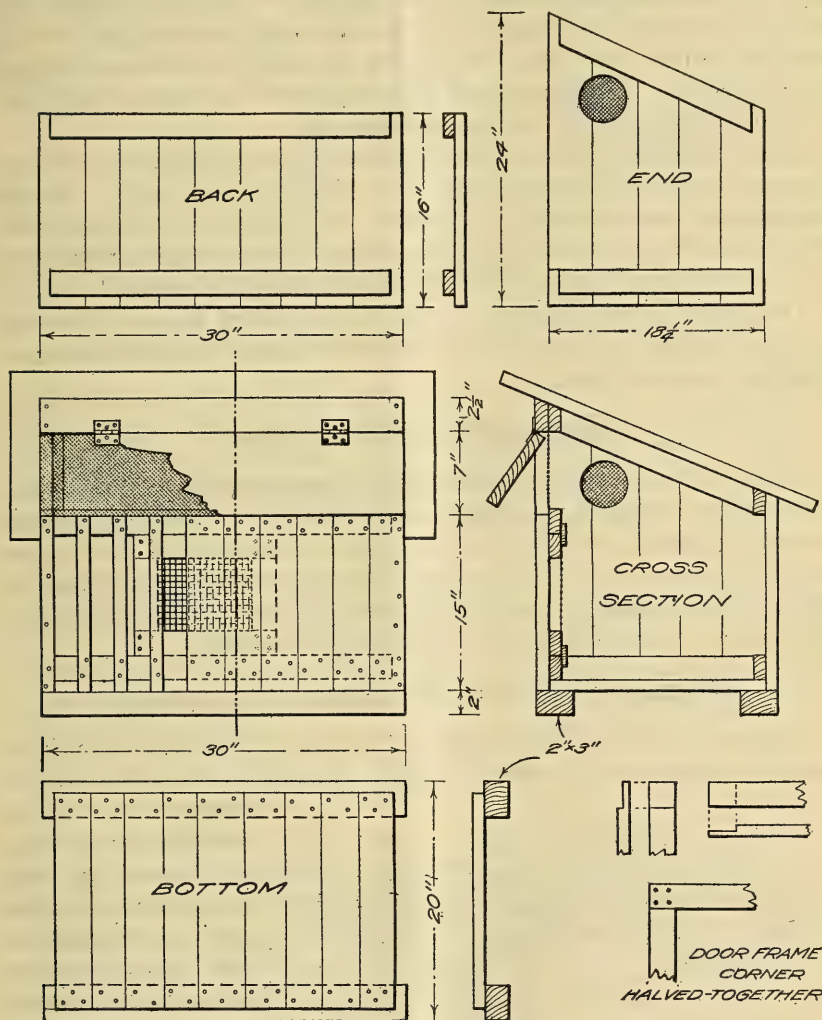


FIG. 35.—Brood coop.

above flooring and bottom nailer $\frac{1}{8}$ inch above bottom of flooring. Next, make sliding door $\frac{1}{2}$ inch smaller than distance between nailers and 17 inches long. Do this by fastening together with screws four 1 by 2 inch strips of proper lengths halved together at the angles, as shown in the illustration. Tack piece of wire netting 9 by 15 inches to this frame, and the door is ready to place with wire cloth on inside

of coop, between the nailing strips. To hold this door in between the slides, nail a piece of $\frac{1}{2}$ by 2 inch stop to top and bottom nailers as shown. If you haven't a piece of this stop, a lath, a piece of beveled siding, or a strip of tin or galvanized iron may be used.

Assemble the sections thus far completed. To do this place the back and one end in position on the bottom and nail the back to the end. Then place the other end in position and nail the back to it as you did at the other end. Next, put the front in position and nail to both ends. *Do not nail back ends or front to the bottom;* the coop is to be lifted from the bottom to clean it.

Finish up the front by nailing a piece of 1 by 2 inch across the top between the ends, and tack the piece of wire netting to it. Cut 30 inches from the piece of 1 by 3 inches by 3 feet and 30 inches from the piece of 1 by 7 inches by 3 feet, hinge the two together with the 2 by 2 inch butts, and nail the 1 by 3 inch into place across the top.

The coop is now ready for a roof. Cut enough pieces of flooring 4 inches longer than slope of end of coop to cover 34 inches and nail them to front and back.

EXERCISE XVI. POULTRY HOUSE.

To carry on a home project in poultry some type of poultry house is necessary. Often boys of the rural schools will desire to construct houses. Plans, specifications, and bills of material for good types are given in Farmers' Bulletin 574. Pupils desiring to build poultry houses should write to the United States Department of Agriculture for a copy of this bulletin and follow the plans given.

EXERCISE XVII. WOODEN TROUGHS FOR SWINE.

In figures 36 and 37 are shown two types of wooden troughs that are used extensively by swine raisers. The one shown in figure 36 is

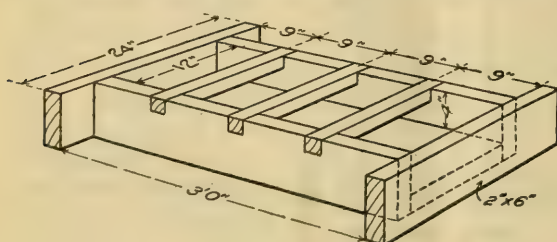


FIG. 36.—Trough for young pigs.

designed for use in feeding young pigs. As shown in the drawing it is shallow and is constructed with a flat bottom and wide end pieces. The shallowness makes it easy for the young pigs to get at

the feed, and the wide ends make it difficult for the pigs to overturn it. The cross pieces prevent the hogs from lying in the trough. The drawing gives all necessary dimensions. Make out a bill of material and a bill of stock, cut the pieces, and assemble them.

Figure 37 shows a V-shaped trough for older hogs. Like the one shown for young pigs, it is wide at the ends and provided with cross pieces. The drawing gives all necessary dimensions. Make out bills of material and stock, and construct.

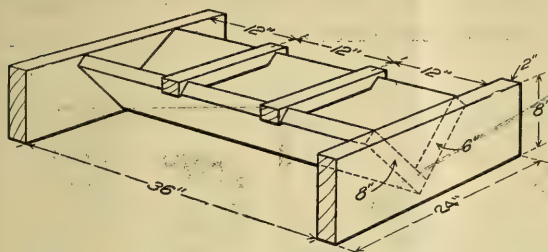


FIG. 37.—Trough for mature hogs.

NOTE TO TEACHER.—Where pig projects are a feature of school work the boys will be interested in building troughs such as are described in this exercise.

This exercise and some of those that follow will fit well with the class instruction dealing with swine raising as well as with the club work.

EXERCISE XVIII. HURDLES FOR USE IN STOCK JUDGING.

A hurdle as described in this exercise is a panel of boards made as shown in figure 38. Hurdles are portable and are useful when sorting hogs or sheep into groups or keeping the animals, especially hogs, separated when scoring and judging them. Three or four hurdles fastened together at the ends make a very good temporary pen.

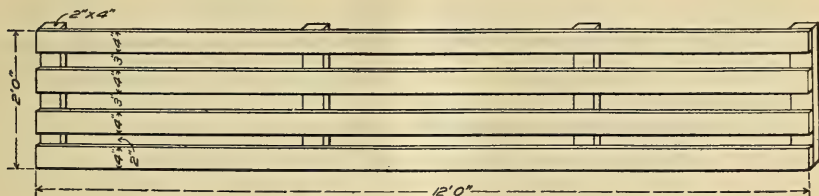


FIG. 38.—Hurdle.

The materials required are four pieces 1 by 4 inches by 12 feet, one piece 2 by 4 inches by 8 feet, and 2 pounds of eightpenny common nails. To build the panel, cut the pieces as shown in the drawing. Lay the four pieces of 2 by 4 inches on the floor, spacing them 4 feet apart, nail the bottom board, space 2 inches and nail the second board, space 3 inches and nail the third board, nail the fourth board on the top.

EXERCISE XIX. HOG HOUSES.

The members of pig projects will need some kind of hog house. Farmers' Bulletin 438, entitled "Hog Houses," gives some very practical plans for houses, and those desiring to use this exercise should send for a copy of this bulletin and follow the directions given.

EXERCISE XX. MILKING STOOL.

A very substantial milking stool is illustrated in figure 39 and described in this exercise. The material required is one piece of white pine 1 by 8 by 21 inches, one piece 2 by 4 by 14 inches, a few

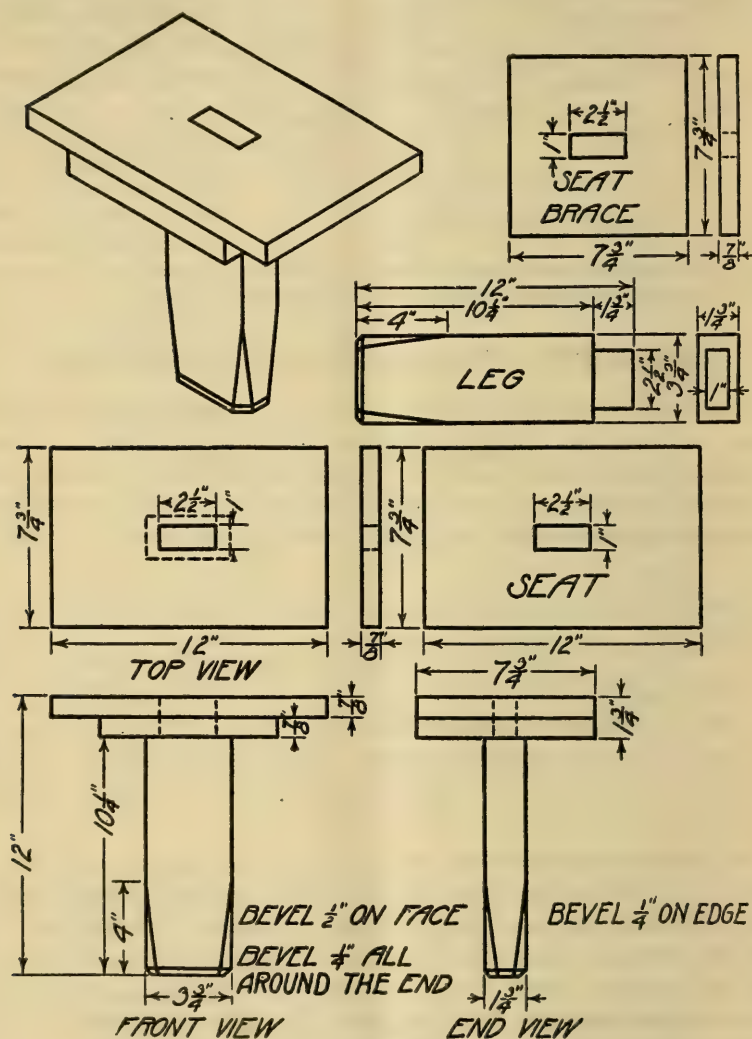


FIG. 39.—Milking stool.

8-penny nails, and a hardwood wedge. The bill of stock with finished dimensions and the use of the parts are as follows:

Use.	Number of pieces.	Finished dimensions.
Seat.....	1	Inches. 7 by 7 3/4 by 12.
Seat brace.....	1	7 3/4 by 7 3/4 by 7 3/4.
Leg.....	1	1 1/4 by 3 3/4 by 12.

Cut the seat and seat brace from the 21-inch board and square up the pieces to the dimensions given in the bill of stock. Place the seat brace in position on the bottom of the seat, having the grain of the seat brace crosswise of the grain of the seat. Nail the two pieces together, driving the nails from the top and clinching them on the bottom of the brace piece. Lay out the mortise on both sides of the two pieces, as shown in the drawing. Bore three holes with a $\frac{3}{4}$ -inch bit inside of the lines and trim to these lines with a $\frac{3}{4}$ -inch chisel.

Cut the leg from the piece of 2 by 4 inch, squaring it up to dimensions and beveling it as shown in the drawing. Lay out the tenon on the end as called for in the drawing. Saw to the lines and trim the tenon smooth with a $\frac{3}{4}$ -inch chisel. See that it will fit snugly into the mortise of the seat. Saw a slot in the tenon for a wedge. This should be made lengthwise and through the center of the tenon.

To assemble the leg and seat, slip the tenon into the mortise and drive a small hardwood wedge into the slot of the tenon. This will hold the leg and seat together firmly.

Bore a $\frac{3}{4}$ -inch hole in the leg near the end to provide a means for hanging up the stool when it is not in use.

EXERCISE XXI. CALF STANCHIONS.

When calves run together in a pasture or feed lot, a row of stanchions should be provided in order that each calf may be held until it gets the proper quantity of feed and to prevent it from sucking the next one's ears. Figure 40 illustrates this exercise and describes a practical row of stanchions for this purpose. White pine, spruce, or hemlock may be used. The bill of material is as follows:

Quantity.	Dimensions.	Quantity.	Dimensions.
1 piece.....	1 by 5 inches by 12 feet.	1 piece.....	1 by 8 inches by 12 feet.
1 piece.....	1 by 4 inches by 12 feet.	3 bolts.....	$\frac{3}{8}$ by 3 $\frac{1}{2}$ inches.
1 piece.....	1 $\frac{1}{4}$ by 4 inches by 12 feet.	3 pair light strap	
1 piece.....	1 $\frac{1}{4}$ by 4 inches by 10 feet.	hinges.	
1 piece.....	1 $\frac{1}{4}$ by 5 inches by 7 feet.	2 pounds eight-	
		penny com-	
		mon nails.	

From the piece of 1 $\frac{1}{4}$ by 5 inches by 7 feet cut two pieces 3 feet 6 inches long, and from both the 1 by 5 inches by 12 feet and 1 by 4 inches by 12 feet cut two pieces 6 feet long. Then nail the ends of the 1 by 4 inch by 6 foot pieces to the top of the 1 $\frac{1}{4}$ by 5 inch by 3 foot 6 inch pieces, as shown, nailing the 1 by 4 inch pieces on each side of the upright. Nail the two pieces of 1 by 5 inches by 6 feet in the same way, 18 inches below the top board.

From the 1 $\frac{1}{4}$ by 4 inches by 10 feet and 1 $\frac{1}{4}$ by 4 inches by 12 feet cut the stanchion boards, as shown. Nail a piece of 1 $\frac{1}{4}$ by 4 inch

between the top and bottom rails as shown, leaving a 2-inch space between the corner upright and this piece. Next, space 4 inches from this bar to the swinging bar, drop the bar in place between the rails, and with a brace and $\frac{1}{2}$ -inch bit bore a hole through the center of the 5-inch rail and 4-inch bar and insert one of the 3-inch bolts. Space again 4 inches from the bar and nail in the next bar. Proceed in this way with the remaining stanchions, then nail the two pieces of 1 by 8 inch by 6 foot to the back of the two end uprights, as shown.

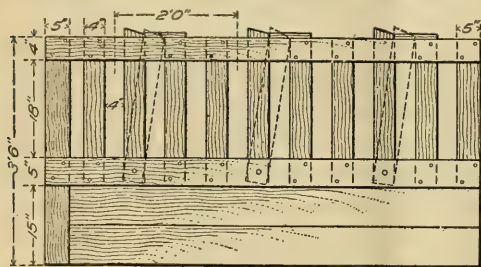


FIG. 40.—Calf stanchion.

a way that when the swinging bar is in closed position this block will drop in place and hold the bar.

NOTE TO TEACHER.—This exercise will fit into instruction in either dairying or beef raising. Boys who feed calves at home will be especially interested in these stanchions.

EXERCISE XXII. FARM GATE.

In figure 41 is shown a very good type of farm gate. The constructing of such a gate is not especially difficult and makes a very good exercise in farm mechanics for farm boys.

For a gate 12 feet long the material required is:

- 1 piece 1 by 4 inches by 14 feet.
- 7 pieces 1 by 4 inches by 12 feet. (White pine or other dressed lumber.)
- 1 pair bolt and eye gate hinges with bolts.
- 3 pounds 8-penny common nails or 5 pounds $\frac{1}{4}$ by 2 inch bolts.

From the piece of 1 by 4 inches by 14 feet cut two pieces of 4 feet 2 inches long. Space the boards as shown in the illustration, placing the two upright pieces 12 feet apart from outside to outside. First, nail six of the 1 by 4 inch by 12 foot boards to the strips. Next, nail the remaining 1 by 4 inch by 12 foot piece as a diagonal brace. Be sure to have this brace run to the bottom hinge end of the gate. From what is left of the 1 by 4 inch by 14 foot piece cut the two short braces as shown, and nail the diagonal and short braces to each board.

Bolts may be used instead of nails to fasten the boards together. They are a better construction, but somewhat more expensive.

To adjust the hinges, bore a hole through the gate post, insert the bolt member of the hinge, and fasten it to the post by screwing a nut on the opposite side of the post. Having fastened the bolt to the post, place the eye member of the hinge on the bolt and determine how much space is required between post and gate. This is usually about 3 inches. Allow 1 inch more for play between the gate and the opposite post if the gate is to swing clear, both ways, between posts. Thus, for a 12-foot gate the posts should be 12 feet 4 inches apart. Screw the eye members in place, and the gate is ready to hang.

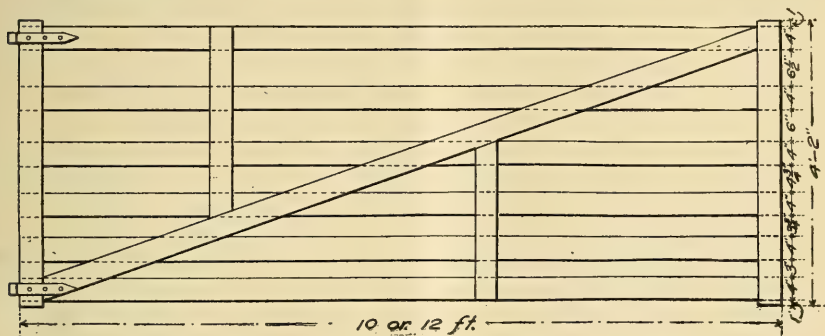


FIG. 41.—Farm gate.

EXERCISE XXIII. ROPE WORK.

The whipping and crowning of rope and the tying of various knots and hitches provide practical work for pupils in the seventh and eighth grades. Rope-tying contests will add interest to a Friday-afternoon program. Bulletins issued by the extension service of the agricultural colleges of some States have described and illustrated this rope work thoroughly. In other States, where these bulletins are not available, teachers will find the manual of the Boy Scouts of America very helpful. The boy scout is required to learn to tie knots and is examined as to his proficiency in this in much the same way as might be done at school.

EXERCISE XXIV. CONCRETE WORK.

Concrete work, such as the making of posts, floors, and sidewalks, is a type of farm mechanics that appeals to farm boys. In many cases teachers can have the boys build a fence or a sidewalk for the school grounds. Usually the shovels, trowels, and other tools necessary will be brought from home by some of the pupils. Many boys who have practice in concrete work at school will continue the work at home. Instructions for working this exercise are found in three Farmers' Bulletins, and these should be requested from the

United States Department of Agriculture and the directions followed. No. 461 gives instructions for mixing and placing concrete; No. 403 tells how to make concrete fence posts; and No. 481 tells how to lay a concrete feeding floor. A sidewalk is laid in a similar manner.

EXERCISE XXV. THE PAINTING OF WOODWORK.

Some of the articles made in the exercise will need to be painted. For information regarding the mixing and handling of paint, see Farmers' Bulletin 474. Write to the United States Department of Agriculture for a copy of this bulletin and follow the directions given.

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UNITED STATES DEPARTMENT OF AGRICULTURE

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OFFICE OF THE SECRETARY

Contribution from the Office of Farm Management.

W. J. SPILLMAN, Chief.



Washington, D. C.



April 13, 1917

SEASONAL DISTRIBUTION OF FARM LABOR IN CHESTER COUNTY, PA.

By GEORGE A. BILLINGS, *Agriculturist.*

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PART I.—CHESTER COUNTY (PA) DATA.

The purpose of this bulletin is (1) to set forth the actual labor distribution that prevails on farms profitably conducted in a particularly successful farming community, and (2) to show how these data may be applied profitably in replanning a farm of the type covered in the survey upon which this study is based.

It often happens that when a farmer undertakes to put into operation a new system he encounters grave and unforeseen difficulties through the conflict of the labor and equipment demands of his different enterprises. Even more frequently it happens that long existing farming systems chronically suffer in their operations through the strenuous labor demands of certain seasons and through the enforced idleness of others. When an abundance of day labor, both man and horse, is easily and continually available, the problem is never a serious one. There is, however, a great advantage in being able to employ labor by the season or by the year, and it is practically necessary to keep on the farm horses and equipment adequate to

meet the maximum demands of the rush season. It is important, therefore, that the farmer contemplating a change in his cropping system should have some method by which he may measure the labor requirements of a proposed system to determine its feasibility under his limitations as to labor and equipment. It is equally important for the farmer who is already encountering difficulties through conflicting labor demands to be able to make an analysis of his system with a view to making changes that will obviate these difficulties. It is to give these farmers a basis upon which to plan with reference to seasonal distribution of labor that this bulletin has been prepared.

TERRITORY SURVEYED AND METHOD USED.

The region studied was the southern part of Chester County, Pa. It extends from the Maryland line on the south to the Chester valley on the north, and from the more broken region in the western part of the county to the vicinity of West Chester on the east. It includes the region already covered by a farm-management survey¹ made by this department, and, in addition, areas outside of this area having similar agricultural conditions.

This special study was conducted in the summer of 1915. Only the more successful farms were visited, that is, those yielding labor incomes above the average found in the previous farm management survey. In that study the average of 389 farm owners was \$789. The 215 farmers visited were selected from this list except a few from closely adjoining territory. The object of this survey was to study the farm practice and labor efficiency of well-managed farms, to the exclusion of others.

By "labor income" is meant the amount of money that the farmer has left after paying all business expenses of the farm and deducting 5 per cent for interest on the money invested in the farm business.

By "farm practice" in this connection is meant the general order of performing the various farm operations, from the application of manure, plowing, and preparation of seed bed to the marketing of the crop. Data as to the different types of implements and other equipment used, information concerning the use of commercial fertilizers, the methods of cultivation employed, and the yield and disposition of the products were obtained in the study of farm practice.

By "labor efficiency" is meant the number of loads or tons handled or the area covered by an implement with a definite crew of men and horses, in a day or other unit of time, for every operation in the growing of the crop. In this connection estimates were obtained from the farmer as to the number of days actually available for field work throughout the growing season, the number of days actually worked

¹ "Farm Management Practice in Chester County Pa.," U. S. Dept. Bulletin No. 341.

in hauling manure or marketing a crop in winter, and the average number of hours worked per day for each month. From the data on the distribution and efficiency of labor, factors have been worked out by which it is possible to calculate very closely the amount of horse and man labor required for any cropping system and for any arrangement and acreage of crops, provided of course that topography, climate, and other conditions approximate those that obtain where this study was made.

The second part of the bulletin illustrates the application of these data and the factors derived therefrom in the operation of a typical Chester County farm, offering a concrete example that may be used to more or less advantage by the farmer who wishes to replan his farming system along the lines here suggested.

LABOR EFFICIENCY AS AFFECTED BY SOIL, TOPOGRAPHY, AND FIELD ARRANGEMENT.

The average efficiency for any crew working tillage machinery will vary to some extent with the kind of soil, the size and shape of the field, the rough or rolling nature of the field, and the amount and distribution of rainfall. These things must be considered, therefore, when the following data are to be used in regions where the conditions vary to any considerable extent from those that prevail in Chester County.

The surface soil of the Chester loam,¹ which is mapped on the greater part of this area, is a mellow, soft, brown silty loam about 10 inches in average depth, sometimes varying from a silty to a heavy loam, or to a sandy or micaceous loam. Under average climatic conditions these soils work comparatively easily when 1,200 to 1,400 pound horses are used. The soil does not easily crust or bake. Under very dry conditions it is sometimes rather difficult to plow, and some allowance should be made if clover, timothy, or alfalfa seedings are to be made in August.

The general shape of the field has much to do with the efficiency of horse labor. Where the topography is rolling and but little broken by rough wooded areas or streams the general arrangement of the fields may be changed to economize labor. In Chester County, however, we have conditions very hard to change, since the area studied is often much broken by small streams with adjacent steep slopes, often wooded, dividing the farming area into natural divisions with irregularly shaped fields which require an unusual amount of horse labor in handling farm machinery.

It is for this reason, probably, that the average number of crop acres per horse on the farms visited is less than on the farms surveyed in certain other regions. On many farms visited, however, a rear-

¹ Soil Survey of Chester County, Pa.

rangement of fields would no doubt be a strong factor in enhancing labor efficiency. Long rectangular fields require a minimum of turning, and therefore entail the least waste of time in handling implements, and there is little doubt that the averages in the labor requirements given in the following tables could be reduced if due attention were given to this detail.

The climatic conditions in this region are comparatively uniform. The average amount of rainfall for 33 years at Kennett Square is 49 inches, and the average monthly rainfall for the six summer months during this period is 4.6 inches. Under good soil management, such as has been followed on the farms visited, the soils are generally retentive of moisture, intertilled grain crops suffer but little, and the season is exceptional that forces the farmer to break the regular routine of plowing or preparation for seeding.

TYPES OF FARMING.

Few agricultural regions have a more uniform type of farming than that found in southern and central Chester County. The character of the soil is especially adapted to the growing of forage crops and grain, especially corn, wheat, clover, and timothy. These favorable conditions and the fact that this region is convenient to good markets—Philadelphia, Pa., and Wilmington, Del.—is probably the reason why general farming and dairying is the principal type of farming in this region. The systems of farming followed have not materially changed in the last 50 years.

The fruit industry until recently has been confined to the home orchard, which, as a rule, has received but little care and has given but little return. However, on selected slopes where the drainage is good, apples are now commanding increased attention. A number of new orchards have been planted, and the returns from those orchards which have begun to bear indicate a future for the fruit industry.

Hitherto soy beans have not been grown in Chester County to any great extent, but it is believed that this is a crop which may profitably take the place of oats in the rotation. The acreage in oats has decreased in recent years. Evidently the farmers are finding this crop unprofitable. Soy beans have been successfully grown by a few Chester County farmers, and their great advantage from a farm management standpoint, in that the product has a high feeding value, can be harvested for hay or grain, and that the crop has considerable influence in soil improvement, makes this legume a promising crop for this region.

Three years ago less than 1 per cent of the farmers visited grew alfalfa, but the acreage has been rapidly increasing since then. How-

ever, if alfalfa becomes a prominent hay crop, this may have a marked effect on the cropping systems.

The production of corn, wheat, and hay combined with live stock—generally dairy cattle—brings the most uniformly profitable returns to the Chester County farmer. Beef cattle are found only on a few of the larger farms.

The rotation generally practiced by all farmers, as well as as those visited, is as follows:

1. Corn planted on timothy sod, usually harvested for grain, but sometimes for silage.
2. Corn for silage, potatoes, oats, or soy beans.
3. Wheat.
4. Clover and timothy for hay.
5. Timothy for hay, one or two years.

There is practically no change in the order of succession of these crops, and all variations usually come the second year after breaking the sod.

VARIATIONS IN METHOD.

Manure is generally applied for corn, potatoes, alfalfa, and often as a top dressing on mowing land and pasture. It is seldom applied for wheat or oats. About 50 to 60 per cent of the 165 farmers from whom labor records were obtained haul out manure only in the spring and fall, 5 to 10 per cent do so daily, and the remainder weekly. There is little difficulty, however, in finding a place to spread manure profitably at any season of the year.

The greater number of these farmers plow in the spring, though considerable areas of sod are often fall plowed. Except on steep slopes, which are apt to wash badly, fall plowing of sod is of advantage because it will facilitate spring work.

There is more or less variation even among the best farmers in the preparation for seeding. It is their universal practice, however, to roll or plank-drag a field immediately after plowing, to compact the soil, level, and give a surface better fitted for the action of the harrow which follows. The majority of these farmers use a disk harrow, working it one or more times for each crop, which is usually followed by a spike-tooth smoothing or a spring-tooth harrow, finishing the preparation with a roller or plank-drag. Until recently the spring-tooth harrow was generally used on these farms, but this is being replaced by the disk harrow. A large number of these successful farmers, however, entirely prepare for seeding with a spring-tooth harrow and a plank-drag. The spike-tooth harrow is not in as general use here as in some other regions, and is used largely in surface finishing preparatory to seeding and for harrowing corn or potatoes just preceding cultivation. The weeder is little used, its place being taken by the spike-tooth harrow.

There is a growing opinion among farmers in the part of Chester County where these records were taken that midsummer plowing should not be done, but the preparation for wheat, for alfalfa, and for timothy and clover seeded in August should be with disk and surface harrows only. This opinion is backed up by demonstrations from a number of farmers. They reason (1) that it is very hard to compact the soil after plowing at this season of the year so as to obtain good moisture conditions for seeding; and (2) that by plowing the farmer turns under roots, stubble, and other humus material and brings up soil containing less humus, which makes the field more apt to wash badly during the winter and early spring season. If disk harrowing is done at the proper time there is very little difficulty in working under stubble or manure and obtaining a firm, fine seed bed. There is little difference, however, between the two systems in the amount of labor required.

When fertilizer is applied for corn it is distributed broadcast more often than in the planter; on the other hand, fertilizer for potatoes is seldom broadcasted, but applied in the row at the time of planting.

The practice of applying lime once during the rotation is increasing. Years ago farmers used burned lime freely, and many farms in the county still show abandoned lime kilns. Then the practice of using commercial fertilizers gradually replaced the general custom of applying lime until the soils got into such a condition that the practice of liming the soil had to be resumed. The application of caustic lime in the form of burned stone lime, slaked, and applied by hand is gradually being superseded by the use of ground stone lime, prepared hydrated lime, or finely ground limestone. This is undoubtedly due to the fact that burned or stone lime must be slaked before applying while the pulverized forms of lime or limestone can be handled more conveniently by a distributor. In fact, it was impossible to obtain sufficient labor data for handling lime by hand, as the lime spreader is generally used. Lime is usually applied at the time of preparation for wheat, for clover and timothy, or for alfalfa in order to obtain a good stand of these legumes.

While these farmers grow from 1 to 5 acres of potatoes, or an average of about 4 acres, this crop, as a rule, has not given profitable yields; the average yield on the farms visited was only 84 bushels per acre. The cause of this low yield is not easily determined, and it might well be made the subject of investigation and experimental work. Very little spraying is done for blight; what spraying is done is usually to apply poison for the potato beetle. The potato planter is generally used among the larger growers, but digging is more often done by the potato plow type of implement than by the elevator type of machine.

The ordinary method of seeding to clover and grasses in the region studied is to drill in timothy at the time of seeding wheat and broadcast clover in the spring before the ground has settled. The dry and hot weather in summer has a tendency to burn out the young clover in wheat. Hence, the practice of preparing wheat stubble and seeding both clover and timothy in August obviates this difficulty and this method of seeding is being more generally practiced.

The results obtained seem to justify the additional labor required for preparation and seeding. The writer has observed many excellent crops of clover obtained by this method of seeding, whereas by the old method it is quite common to see an overabundance of white top and other weeds. Where seeding clover in wheat is still done, clipping the wheat stubble in July or August has resulted in a better and cleaner growth the following year.

The practice of mixing alfalfa with clover and timothy for August seeding is strongly recommended by a few farmers in order not only to assist in inoculating the soil with the alfalfa bacteria, but also to improve the quality of hay. The following seed mixture has given good results: 5 to 6 quarts of alfalfa, 4 quarts of red clover, 3 quarts of alsike clover, and 2 to 3 quarts of timothy. This will usually give two cuttings annually, and sometimes three cuttings. The first will be largely of timothy and clover and the later cuttings almost pure alfalfa.¹

Under good weather conditions, clover and timothy hay requires very little handwork except in loading and storing, and a hay loader is used on many farms. The advantage of its use, however, is doubtful with clover and alfalfa. Hay caps for protecting alfalfa are used only on a few of the farms visited, but those who do use them believe that they are of decided advantage, with very little additional labor in harvesting, and that the increased value of the hay, due to improvement in quality, is sufficient to justify their use. This improvement in quality is due to the saving of the leaves of the plant and the preservation of its original green color. The soy bean, in labor requirements, does not seriously compete with other field crops. While the preparation of oats usually interferes with the planting of corn or potatoes, ground for soy beans, on the other hand, may be prepared and planted after corn has been planted, and the crop can be harvested for hay before silo-filling time, or as grain after the corn crop has been cut. In either case, the land can be cleared in time to sow to fall grain.

¹ In order to be sure of a permanent stand of alfalfa, farmers should give attention to the essentials as to the quality of seed, use of lime, inoculation, and the preparation of the seed bed for alfalfa adopted by successful growers as the result of years of experience in the region and other regions having similar agricultural conditions.

AVAILABLE TIME FOR FIELD OPERATIONS.

In order to determine whether it is possible to carry out a proposed cropping system with a certain amount of man or horse labor, it is necessary to know the approximate number of days available for field work and the average length of the workday. This is given in Table I on a monthly basis.

TABLE I.—*Available days for field work and hours in workday.*

Data.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Days available.....	3	3	10	16	19	21	22	22	21	17	14	6
Hours in workday.....	7	7	8	9	9	9	10	9	9	9	8	8

These figures were the averages of 195 farmers' estimates. The farmer was asked to give the average number of days actually available for field work each month, after deducting Sundays, rainy days, and days when the condition of the soil would prevent field operations. Plowing is sometimes done in December and March, but the figures in those months include also the time spent in hauling manure. An average of three days each for January and February also represents time spent in the same work.

TABLE II.—*Number of days (exclusive of rainy days and Sundays) available for the several field operations.*

Operation.	Corn.	Oats.	Potatoes.	Wheat.	Timothy and clover.	Alfalfa.
	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>
Preparation and seeding.....	30	15	16	32	59	25
Cultivation.....	21		29			
Harvesting.....	31	15	15	10	16	8

¹ This does not include thrashing which is hired done.

² Includes seeding clover and timothy in August, or timothy alone with wheat. In the latter case clover is seeded Apr. 1 to 18 following.

Table II gives the average number of days that labor can be performed in the field after deducting Sundays, rainy days, and days when the soil is unfit to cultivate, and the period of seeding, cultivating and harvesting of six of the principal crops in this region.

The application of these data will be made when it is necessary to determine whether it is possible to prepare the field, plant, cultivate, or harvest certain acreages of crops with a given field force. The preparation for corn, oats, and potatoes to a certain extent overlaps, and the farmer not infrequently plans for a greater acreage than can be planted within the limits of successful crop production. Moreover, in the case of a late spring, it is important to figure on the extra labor necessary to carry out the cropping plan or else reduce the acreage of these crops within the limits of the regular farm labor.

PERIOD OF PERFORMING FIELD OPERATIONS.

There is a considerable variation in the length of season for doing various farm operations, according to the 165 labor records, yet the average of these data obtained and charted is not far from the actual period in which most of the farmers perform these operations; at least it is sufficiently accurate to use as a guide in planning the cropping system. Figure 1 gives the period of performance of the various farm operations for corn, potatoes, oats, wheat, clover and timothy, and alfalfa.

SUCCESSION OF OPERATIONS.

Before any plan can be worked out showing the labor requirements and the general distribution of labor, the succession of farm operations with any crop must be known. The aim has been to standardize the field operations and arrange them in the order in which they are usually performed. There is considerable variation even among the more successful farmers in the manner of preparing the ground and handling the crop. The outline which follows gives the order which the greatest number of these farmers follow, with the important variations.

CORN.

(1) *Manuring*.—On sod, August to December; on stubble, early spring; 12 tons to acre. (2) *Plowing*.—Generally in spring; 12 or 14 inches, walking plow. (3) *Rolling or planking*.—Immediately after plowing. (4) *Harrowing*.—Majority use 4-horse double disk, working once each way, following with spring-tooth or spike-tooth harrow. Forty-five per cent of these farmers use spring-tooth harrow only, harrowing two to four times in different directions. (5) *Drilling fertilizer*.—With grain drill. (6) *Rolling or planking*. (7) *Planting*.—With two-row planter. (8) *Weeding*.—Spike-tooth harrow used before regular cultivation begins. (9) *Cultivating*.—Usually four times with 2-horse and once with 1-horse. (10) *Cutting and shocking*.—By hand, 36 hills to shock, binder used occasionally for silage corn. (11) *Husking and hauling*. (12) *Hauling stalks*.

POTATOES.

(1) *Manuring*.—Late fall, winter, or early spring. (2) *Plowing*.—In spring; 12 to 14 inches, walking plow. (3) *Rolling or planking*.—Following plowing. (4) *Harrowing*.—Disk used by 57 per cent of 33 farmers, from whom records were obtained, followed by spike-tooth or spring-tooth harrow; remainder use spring-tooth harrow only, working two or three times. (5) *Planting*.—Few of these farmers plant by hand. (6) *Weeding*.—With spike-tooth harrow, working twice. (7) *Cultivation*.—Four or five times with riding cultivator. (8) *Spraying*.—One to three times for potato beetles; few spray for blight. (9) *Digging, picking, and hauling*.—Many use potato plow type of digger; potatoes usually stored in cellar.

OATS.

(1) *Plowing*.—Usually in spring, sometimes the fall before (oat ground is always plowed). (2) *Rolling*.—After plowing; sometimes before seeding. (3) *Harrowing*.—Spring-tooth harrow generally used by these farmers, working the field twice. (4) *Seeding*.—With 6 to 10 foot drill. (5) *Cutting, shocking, and hauling*. (6) *Thrashing*.

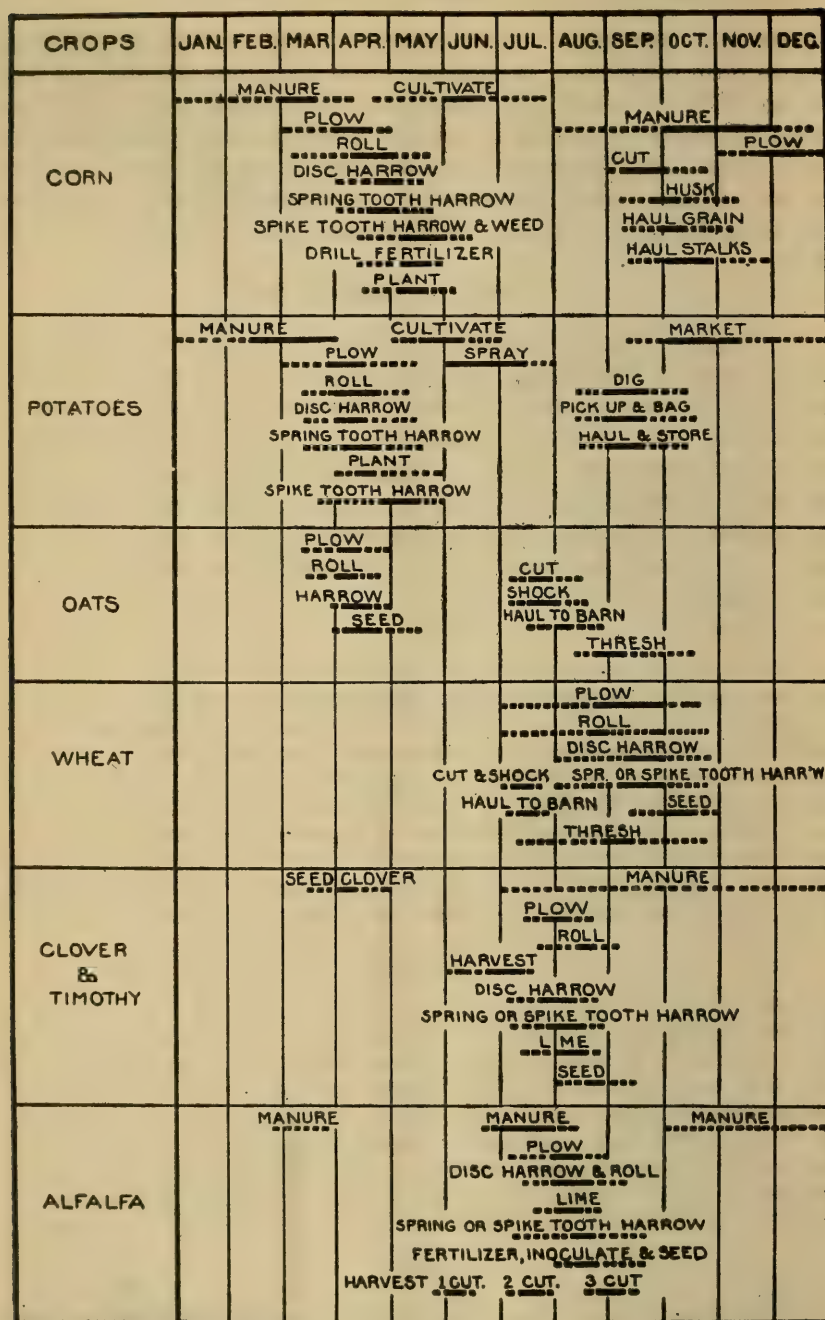


FIG. 1.—Periods of performance of farm operations (Chester County, Pa.). The full line represents the period when most of the farmers perform these operations, and the dotted line gives the range within which these operations may be performed.

WHEAT.

(1) *Plowing*.—Oat stubble, soon after harvesting, land allowed to lie fallow until about October 1; when wheat follows potatoes or corn the ground is plowed (sometimes only disked) immediately after the harvesting of those crops. (2) *Rolling or planking*.—After plowing, sometimes also before seeding. (3) *Harrowing*.—Majority of the farmers visited use disk followed by spring-tooth or spike-tooth harrow; many use spring-tooth harrow only, working two or three times; when disk is used instead of plow, the ground is worked four to six times. (4) *Seeding*.—With drill. (5) *Harvesting*.—With 3-horse 6-foot binder. (6) *Hauling*.—To stack or mow. (7) *Thrashing*.—Done at barn, occasionally in the field.

TIMOTHY AND CLOVER.

(1) *Manuring*.—As top dressing on sod, in fall or winter; on new seeding, in summer. (2) *Plowing*.—Often soon after wheat harvest. (3) *Rolling or planking*.—After plowing; sometimes again before seeding. (4) *Harrowing*.—Nearly 50 per cent of the farmers visited use disk, followed by spike-tooth harrow; many use spring-tooth harrow only; a few use disk followed by spring-tooth harrow. (5) *Liming*.—Usually after wheat harvest when the land is prepared and seeded in August. (6) *Seeding*.—Timothy is seeded with wheat, and clover the following April; about 23 per cent prepare wheat stubble and seed in August. (7) *Harvesting*.—With 5-foot mower; hay fork is used and hay loader frequently.

ALFALFA.

(1) *Manuring*.—About 12 tons per acre as a top dressing or at seeding of previous crop. (2) *Plowing*.—Disk gaining in favor. (3) *Rolling or planking*.—Immediately after plowing; again between harrowings and often after seeding. (4) *Harrowing*.—Disk is generally used by these farmers, working twice after plowing; double disk three to six times when plow is not used; spring-tooth harrow sometimes follows disking, but more often follows plowing without disking. (5) *Liming*.—With the distributor, except in a few instances. (6) *Inoculation*. (7) *Seeding*.—With drill or wheelbarrow seeder, 20 to 25 pounds per acre. (8) *Cutting*. (9) *Tedding*.—Tedder not always used when followed by side-delivery rake. (10) *Raking*.—Side-delivery rake generally used; some of the smaller farms use a dump rake. (11) *Cocking*.—Immediately after raking when the hay is to be protected with hay caps; in this case hay stands in cock for one to three days and is opened up two hours before hauling. (12) *Hauling*.—Where a loader is used the hay is picked up from the windrow. (13) *Top dressing*.—Manure sometimes applied in fall; fertilizer in early spring or immediately after first or second cutting. (14) *Harrowing*.—Disk or special sharp-pointed spring-tooth harrow often used after cutting, to eradicate blue grass and weeds.

CREWS AND MACHINERY.¹

In order to determine the amount of labor in man-days and horse-days necessary to perform any operation, it is necessary to know the crew, that is, the number of men and horses, the number of acres covered in a 10-hour day, or the number of tons or loads handled in the same period of time, and the average length of the work day. If these data are in tons or loads, by knowing the capacity of the wagon, the rate of application, and the yield of crop, the acreage covered can be obtained. From these data the day's work per acre for man or horse can be determined.

¹ See U. S. Department Bulletin No. 3, A Normal Day's Work for Various Farm Operations.

TABLE III.—*Crews and duty of machinery in plowing and preparation of soil (average of 165 farms).*

Operation.	Crew.		Acres covered in 10-hour day.	Days per acre.			
	Men.	Horses.		10-hour day.		9-hour day.	
				Man.	Horse.	Man.	Horse.
Manuring, ¹ 12 loads, 14.4 tons.....	1	2	1.44	0.7	1.40	0.77	1.54
Manuring, ¹ 14 loads, 16.8 tons.....	2	2	1.68	1.19	1.19	1.50	1.50
Manuring, ² 14 loads, 16.8 tons.....	3	2	1.68	1.79	1.19	2.25	1.50
Plowing, 14-inch walking plow.....	1	2	1.80	.55	1.10	.62	1.24
Plowing, 2-gang plow, 24 inch.....	1	4	3.60	.28	1.11	.28	1.11
Rolling, ³ 9-foot to 12-foot width.....	1	2	15.00	.07	.14	.07	.14
Disk harrowing (single).....	1	2	9.10	.11	.22	.12	.24
Disk lapping half (single).....	1	2	4.50	.22	.44	.25	.50
Disk harrowing (double).....	1	4	9.50	.11	.44	.12	.48
Spring-tooth harrowing.....	1	2	10.00	.10	.20	.11	.22
Spike-tooth harrowing.....	1	2	12.00	.08	.16	.09	.18
Spike-tooth harrowing.....	1	3	13.50	.07	.22	.08	.24
Distributing lime ⁴ (machine).....	1	2	10.50	.09	.18	.11	.22
Hauling lime to spreader.....	1	2	12 loads.	.09	.18	.11	.22
Drilling fertilizer.....	1	2	8.00	.12	.24	.14	.28

¹ With manure spreader, 10 tons per acre.² Spread by hand.³ A plank drag is often used instead of a roller with the same duty per acre.⁴ On the basis of 1½ tons per acre.

Table III gives crews and duty of machinery as the average on 165 farms for plowing and preparation of seed bed for the principal crops of the region. By duty of machinery is meant the amount of work accomplished in a day. For example, one man with a 14-inch plow and two horses will plow on an average 1.8 acres of land. Dividing 1, or the number of men, by 1.8, the result will be 0.55, which means that it takes 0.55 of a 10-hour day, or 5.5 hours, for one man with a team to plow an acre. In the same way, dividing 2, or the number of horses, by 1.8, or the acreage plowed in one day, the result is 1.1, which means that it requires 1.1 days, or 11 horse-hours, to plow an acre. This is expressed in horse-days, or a fraction of a horse-day, rather than team-days, in order to have the figures on a uniform basis, as a crew may be made up of two or more horses. In the same manner, the day's labor per acre is given for the average length of day devoted to field work in that region, which is 9 hours per day, except in July during harvest, when full time is made.

In hauling manure with a crew of one man and two horses, or two men and two horses, a manure spreader was used. The second man in this case helped load and did not make full time, but the day was so broken that very little other work could be accomplished. In the case of a crew of three men with two horses, two wagons were used, one man loading and two men spreading by hand.

The figures for plowing include both sod and stubble, hence for sod the acreage plowed will be a little less and for stubble land slightly greater than the average. Very inconclusive data were obtained on the working of the 2-gang plow, as only a few are in

use. It is quite possible also that the acreage plowed in July and August, when the ground is dry and compact, will be less than the figures given.

The average disk harrow has usually 12 disks in the single and 24 disks in the double acting harrow, from 14 to 16 inches in diameter, with a cutting surface about 8 feet wide. The spike-tooth harrow is usually 2 to 3 section, with a cutting surface of from 8 to 12 feet, and the spring tooth has a cutting surface of from 6 to 8 feet in width. The plank drag is usually made with three planks overlapping, and the man usually rides. Following a deep-working harrow the drag is an excellent tool for leveling and breaking clods.

TABLE IV.—*Crews and duty of machinery in cultivating and harvesting corn (average of 24 farms).*

Operation.	Crew.		Acres covered in 10-hour day.	Days per acre.			
	Men.	Horses.		10-hour day.		9-hour day.	
				Men.	Horses.	Men.	Horses.
Planting (2-row machine).....	1	2	10.50	0.11	0.21	0.11	0.22
Weeding.....	1	1	18.00	.06	.06	.06	.06
Spike-tooth harrow.....	1	2	13.00	.08	.16	.08	.16
Cultivating ¹	1	2	7.70	.13	.26	.15	.30
Cutting:							
50-bushel yield.....	1	0	1.25	.80		.88	
60-80-bushel yield.....	1	0	1.00	1.00		1.11	
80 bushels and over.....	1	0	.85	1.18		1.32	
Husking:							
50-bushel yield.....	1	0	.74	1.35		1.50	
60-80-bushel yield.....	1	0	.53	1.80		2.09	
80 bushels and over.....	1	0	.44	2.27		2.53	
Hauling grain.....	1	2	2.20	.45	.90	.50	1.00
Do.....	2	2	3.20	.62	.62	.70	.70
Hauling stalks.....	2	2	5.00	.40	.40	.44	.44
Do.....	3	2	6.50	.45	.30	.51	.34
Filling silo: ²							
Cutting by hand and loading.....	6	0					
Hauling to cutter.....	4	8					
Feeding the cutter.....	1	0	4.00	3.50	2.00		
Storing in silo.....	2	0					
Running engine.....	1	0					

¹ This operation is usually performed 4 times.

² Average yield of silage corn, 12 tons per acre.

Table IV gives crews and duty of machinery as the average on 24 farms for planting, cultivating, and harvesting corn. Planting is usually done with a 2-row planter. The figures used do not include the drilling of fertilizer in the row at the time of planting, which consumes extra time, and allowance should be made in the acreage planted where fertilizer is applied. The figures for spike harrowing in this table are for harrowing after planting.

Field corn is usually checked 3½ feet each way by most of these farmers, though a number of good corn growers are planting in drills. Silage corn is planted either in drills or in hills. No figures were obtained for hand planting, as the 2-row planter is universally used. Corn is cut and shocked by hand except where it is to be put in the

silo. "Horses" or "gallows" for supporting each shock, which are made by tying the tops of four hills, are often made a number of days before cutting, if there is any danger of the corn blowing over.

The figures for filling the silo are for a large crew that will keep a 16-inch cutter continuously running. Smaller crews often are used to advantage, however. Where a small crew is used, three men cut and load the corn without dropping it in bundles on the ground. Three teams are required. At any given time one will be loading, one unloading, and the third on the road. In unloading, the drivers hand directly to the feeder. No extra man need be employed where a gasoline engine is used. It will be of advantage to keep two men in the silo. Altogether the crew will consist of nine men and six horses, and the day's work per acre, when $2\frac{1}{4}$ acres are cut per day, will be 4 man-days and 2.66 horse-days. Four teams will be required for long hauls.

TABLE V.—*Crews and duty of machinery in planting, cultivating, and harvesting potatoes (average of 33 farms).*

Operation.	Crew.		Acres covered in 10-hour day.	Days per acre.			
	Men.	Horses.		10-hour day.		9-hour day.	
				Men.	Horses.	Men.	Horses.
Cutting seed, 15 bushels.....	1	0	1.00	1.00	.....	1.11	.....
Planting, plowed in.....	3	2	2.50	1.20	0.80	1.33	0.88
Planting, picker type.....	1	2	4.00	.25	.50	.28	.56
Planting, 2-man type.....	2	2	3.50	.57	.57	.63	.63
Spike-tooth harrowing.....	1	2	13.00	.08	.16	.08	.16
Weeding.....	1	1	18.00	.05	.05	.06	.12
Cultivating.....	1	1	4.00	.25	.25	.28	.28
Cultivating, riding.....	1	2	6.10	.16	.32	.18	.36
Spraying (liquid), 4 rows.....	1	1	15.00	.06	.06	.07	.14
Digging with elevator.....	1	4	3.50	.31	1.26	.32	1.28
Digging with potato plow.....	1	2	3.00	.33	.66	.37	.74
Picking up and bagging ¹	1	0	.50	2.00	.....	2.22	.....
Hauling to cellar ²	2	2	3.70	.54	.54	.60	.60
Sorting and bagging in cellar.....	1	0	.80	1.30	.....	1.40	.....
Hauling to market, 2 miles.....	1	2	1.20	.83	1.66	.93	1.86

¹ Average yield from 120 to 130 bushels.

² 9 loads of 50 bushels each.

Table V gives the crews and duty of machinery as the average on 33 farms for planting, cultivating, and harvesting potatoes. The potato planter is used by most of these farmers, but small areas are often planted by hand. These are of two types, the so-called picker machine, and the machine where a second man sits behind and regulates the dropping.

On small areas Paris green, mixed with plaster, is ordinarily used for beetles, but where 4 acres or more are planted, a liquid sprayer applies Paris green or arsenate of lead. A few farmers are spraying for blight.

Digging is done with a potato plow or other digging implement. One man can pick up in barrels or bags behind an elevator digger, on a field free from weeds yielding about 200 bushels per acre, about 100 bushels a day. Under Chester County conditions, however, and particularly after a potato-plow type of digger, 60 to 75 bushels is an average day's work. A few farmers sell immediately after digging, but the greater number store their potatoes and wait for a special market.

TABLE VI.—*Crews and duty of machinery in seeding and harvesting oats (average of 19 farms).*

Operation.	Crew.		Acres covered in 10-hour day.	Days per acre.			
	Men.	Horses.		10-hour day.		9-hour day.	
				Man.	Horse.	Man.	Horse.
Seeding.....	1	2	9.50	0.11	0.22	0.12	0.24
Cutting, binder 6-foot cut.....	1	2	9.00	.11	.22	.....	.....
Do.....	1	3	10.80	.09	.27	.....	.....
Shocking.....	1	0	6.00	.17	.....	.....	.....
Hauling to barn ¹	2	2	6.00	.34	.34	.....	.....
Do.....	3	2	6.50	.46	.30	.....	.....

¹ All the farmers visited hire thrashing done at from 2 cents to 3 cents per bushel, furnishing fuel and board for the hands. Three to five men in addition are often furnished.

Table VI gives the crews and duty of machinery as the average on 19 farms for seeding and harvesting oats.¹

TABLE VII.—*Crews and duty of machinery in seeding and harvesting wheat (average of 33 farms).*

Operation.	Crew.		Acres covered in 10-hour day.	Days per acre.			
	Man.	Horse.		10-hour day.		9-hour day.	
				Man.	Horse.	Man.	Horse.
Seeding 6 to 8 foot drill ¹	1	2	9.50	0.11	0.22	0.12	0.24
Cutting, binder 6-foot cut.....	1	3	10.00	.10	.30		
Shocking.....	1	0	5.40	.18			
Hauling to barn ²	2	2	5.30	.36	.36		
Hauling to barn.....	3	2	5.75	.51	.34		

¹ Timothy can be seeded at the same time that the wheat is drilled, at no extra labor expense.

² All these farmers hire thrashing done at 4 to 5 cents per bushel, furnishing fuel and board for the hands. Three to five men in addition are often furnished.

Table VII gives the crews and duty of machinery as the average on 33 farms for seeding and harvesting wheat. In most cases the wheat is hauled to the barn and thrashed whenever it is convenient

¹ Some of the farmers in this region who were visited expressed their opinion that oats were unprofitable and a number of farmers are substituting soy beans for this crop. However, as but few farmers are growing soy beans, the data obtained were insufficient to present as an average for this crop. The figures given for preparation of land will apply for soy beans. When the crop is planted in rows the acreage planted per day will be greater than for potatoes and less than for corn. The figures given for wheat will apply to soy beans when this crop is drilled broadcast. In harvesting for hay, labor requirements about equal those given for alfalfa.

to obtain thrashers. A few are thrashing from the shock, and this is possible except in very unfavorable seasons.

TABLE VIII.—*Crews and duty of machinery in seeding and harvesting timothy and clover (average of 38 farms).*

Operation.	Crew.		Acres covered in 10-hour day.	Days per acre.			
	Man.	Horse.		10-hour day.		9-hour day.	
				Man.	Horse.	Man.	Horse.
Seeding with wheat drill.....	1	2	10.60	0.09	0.18	0.10	0.20
Clover seeding (wheelbarrow).....	1	0	19.00	.05		.06	
Mowing, 5-foot cut.....	1	2	9.50	.10	.20		
Tedding, 6 to 8 feet wide.....	1	2	14.50	.07	.14		
Raking, dump rake 8 to 10 feet wide.....	1	2	17.00	.06	.12		
Raking, side-delivery rake.....	1	2	16.00	.06	.12		
Piling in field.....	1	0	5.40	.18			
Loading, hauling, and storing: ¹							
8 loads, 1½ tons yield.....	3	2	5.50	.54	.36		
12 loads, 1½ tons yield.....	4	4	8.50	.47	.47		
13 loads, 1½ tons yield.....	5	4	9.00	.55	.44		

¹ Loaded by hand, unloaded with fork. The results will be somewhat increased by the use of a hay loader.

Table VIII gives the crews and duty of machinery as the average on 38 farms for seeding and harvesting timothy and clover. The figures given for broadcasting with a wheelbarrow seeder are for using the seeder one way. Where one-half of the seed is drilled in one direction and one-half broadcasted in a cross direction, simply add the work units for seeding with drill and seeding with a wheelbarrow seeder.

Very few mowing machines wider than a 5-foot cut are used for the ordinary hay crop. The tedder is usually used for clover or for heavy timothy and mixed grasses. Both the dump and side-delivery rakes are used, but the latter is generally preferred. This implement is especially necessary if the hay is loaded with a loader from the windrow. The side-delivery rake will, furthermore, quite largely take the place of the tedder. The figures given for loading, hauling, and storing are based on pitching in the fields by hand and unloading in the barn with a horse fork or sling. Insufficient data were obtained on the use of a hay loader, but there is little doubt that in favorable weather the hay loader would be of decided advantage, particularly with timothy or mixed grasses.

Table IX gives the crews and duty of machinery as the average on 18 farms in seeding and harvesting alfalfa. Alfalfa is a comparatively new crop in Chester County, but a few successful growers were interviewed, from whom data were obtained. Inoculation has been done by applying soil from an old alfalfa field at the rate of 300 or more pounds per acre. Recently commercial cultures have been introduced. While the cost of these cultures usually exceeds the cost of applying soil, the convenience of handling is an important

factor. Cultures can be applied at no extra labor expense other than is required in the application to the seed.

TABLE IX.—*Crews and duty of machinery in seeding and harvesting alfalfa (average of 18 farms).*

Operation.	Crew.		Acres covered, 10-hour day.	Days per acre.			
	Men.	Horses.		10-hour day.		9-hour day.	
				Man.	Horse.	Man.	Horse.
Inoculating with soil.....	1	2	12.00	0.08	0.16	0.09	0.18
Drilling seed alone.....	1	2	14.30	.07	.14	.08	.16
Seeding (wheelbarrow machine) ¹	1	0	9.50	.10	.....	.11	.....
Mowing, 5-foot cut machine ²	1	2	10.00	.10	.20	.11	.22
Mowing, 8-foot cut machine.....	1	2	15.00	.07	.14	.07	.14
Tedding.....	1	2	14.50	.07	.14	.07	.14
Raking, dump rake.....	1	2	17.00	.06	.12	.06	.12
Raking, side delivery.....	1	2	10.00	.06	.12	.07	.14
Cocking.....	1	0	6.00	.17	.....	.18	.....
Capping.....	1	1	20.00	.05	.05	.05	.05
Loading, hauling, and storing: ³							
10 loads, 1½-2 tons yield.....	3	2	5.50	.54	.36	.58	.39
15 loads, 1½-2 tons yield.....	4	4	8.50	.48	.48	.50	.50
16 loads, 1½-2 tons yield.....	5	4	9.00	.55	.44	.60	.48

¹ One-half of the seed sown lengthwise, the remainder town crosswise.

² This record is for the first cutting. Three cuttings are usually made, but the second and third cuttings are lighter, and will require less labor.

³ Loaded by hand and unloaded with fork. The results will be somewhat reduced by using a hay loader.

When hay caps are used, a cap 50 to 54 inches square, of light-weight canvas, is used. These may be weighted at their corners with stones or cement weights, or the cap may be fastened on the hay with wire pins. It is more convenient usually to distribute caps from a spring wagon or one-horse cart.

SUMMARY OF LABOR REQUIREMENTS OF CROPS.

In making use of the following figures on man and horse labor for the several operations in crop production, it is well to bear in mind that the data from which this tabulation was taken were collected from 165 farmers above the average of the county in progressiveness, receiving considerably more than the average net income. These men followed successful methods of soil and crop management, and in most cases laid emphasis on the careful preparation of the soil and careful cultivation. In some cases the number of hours per acre is greater than in some other regions.¹ They are, however, a good guide in estimating labor in this region or other regions having similar conditions. These summary figures are based on the practice of the majority of the farmers, as averaged in the preceding tables. Hence, for any individual case where a system of farm practice is followed differing from that outlined, the labor requirements can be revised and worked out from Tables III to IX.

¹ See "Farm Management," by Prof. G. F. Warren, of the College of Agriculture, Ithaca, N. Y.

FIELD OPERATIONS AND LABOR REQUIREMENTS (165 FARMS).

	Hours of labor per acre.	
	Man labor.	Horse labor.
<i>Corn (for grain):</i>		
Manuring.....	11.9	11.9
Plowing.....	5.5	11.0
Rolling, 2 times.....	1.4	2.8
Disking, 2 times.....	2.2	8.6
Spike-tooth harrowing, 2 times.....	1.6	3.0
Drilling fertilizer.....	1.2	2.4
Seeding.....	1.1	2.1
Cultivating.....	5.2	10.4
Cutting, 70-bushel yield.....	10.0	....
Husking, 70-bushel yield.....	19.0	....
Hauling grain.....	6.2	6.2
Hauling stalks.....	4.0	4.0
	69.3	62.4
<i>Corn (for silage):</i>		
Preparation, seeding, and cultivation.....	30.1	52.2
Harvesting and filling silo.....	35.0	20.6
	65.1	72.2
<i>Potatoes:</i>		
Manuring.....	11.9	11.9
Plowing.....	5.5	11.0
Rolling, 2 times.....	1.4	2.8
Disking, 2 times.....	2.2	8.8
Spike-tooth harrowing, 3 times.....	2.4	4.8
Cutting seed.....	10.0	....
Planting.....	4.1	5.3
Cultivating, 5 times.....	8.0	16.0
Spraying for bugs, 2 times.....	1.2	1.2
Digging.....	3.2	9.6
Picking up and bagging.....	20.0	....
Hauling and storing.....	5.4	5.4
Marketing.....	21.3	16.6
	96.6	93.4
<i>Oats:</i>		
Plowing.....	5.5	11.0
Rolling, 2 times.....	1.4	2.8
Spring-tooth harrowing, 2 times.....	2.0	4.0
Seeding.....	1.1	2.2
Cutting.....	.9	2.7
Shocking.....	1.7	....
Hauling to barn.....	3.4	3.4
Thrashing—hired done by contract.....	....	....
	16.0	26.1

Field operations and labor requirements (165 farms)—Continued.

<i>Wheat:</i>	Hours of labor per acre.	
	Man labor.	Horse labor.
Plowing.....	5.5	11.0
Rolling, 2 times.....	1.4	2.8
Disking, 2 times.....	2.2	8.8
Spike-tooth harrowing, 2 times.....	2.0	4.0
Applying lime.....	1.8	3.6
Seeding.....	1.1	2.2
Cutting.....	1.0	3.0
Shocking.....	1.8	....
Hauling to barn.....	3.6	3.6
Thrashing—hired done by contract.....	....	....
	<u>20.4</u>	<u>39.0</u>
<i>Clover and timothy:</i>		
Seeding (seeded in August)—		
Plowing.....	5.5	11.0
Rolling, 2 times.....	1.4	2.8
Disking.....	1.1	4.3
Spring-tooth harrowing.....	1.0	2.0
Spike-tooth harrowing.....	.8	1.6
Seeding, wheelbarrow seeder.....	.5	....
	<u>10.3</u>	<u>21.7</u>
Seeded in wheat (timothy in fall)—		
Clover seeding in spring.....	.5	....
Harvesting—		
Mowing.....	1.0	2.0
Tedding.....	.7	1.4
Raking, 2 times.....	1.2	2.4
Piling.....	1.8	....
Loading, hauling, and storing.....	5.4	3.6
	<u>10.1</u>	<u>9.4</u>
<i>Alfalfa:</i>		
Seeding (after oats, wheat, or early potatoes)—		
Manuring.....	11.9	11.9
Plowing.....	5.5	11.0
Rolling, 4 times.....	2.8	5.6
Disking, 3 times.....	3.3	12.9
Spike-tooth harrowing, 2 times.....	1.6	3.2
Applying lime.....	1.8	3.2
Drilling fertilizer.....	1.2	2.4
Applying inoculated soil.....	.8	1.6
Drilling one-half the seed.....	.7	1.4
Cross seeding one-half the seed (wheelbarrow).....	.5	0
	<u>30.1</u>	<u>53.2</u>

Field operations and labor requirements (165 farms)—Continued.

	Hours of labor per acre.	
	Man labor.	Horse labor.
First cutting—		
Mowing, 5-foot cut machine.....	1.0	2.0
Tedding.....	.7	1.4
Raking, 2 times.....	1.2	2.4
Cocking and capping.....	2.2	.5
Making over cocks and collecting caps.....	1.6	.5
Loading, hauling, and storing.....	5.4	5.4
	12.1	12.2
Second or third cuttings—		
Mowing.....	1.0	2.0
Raking, 2 times.....	1.2	2.4
Cocking and capping.....	1.7	.4
Repiling and collecting caps.....	1.3	.4
Loading, hauling, and storing.....	3.0	3.0
	8.2	8.2
Harvesting (without using hay caps)—		
First cutting—		
Mowing, tedding, raking, and piling.....	5.7	8.4
Loading, hauling, and storing.....	5.4	5.4
	11.1	13.8

PART II. HOW TO USE THE FOREGOING DATA.

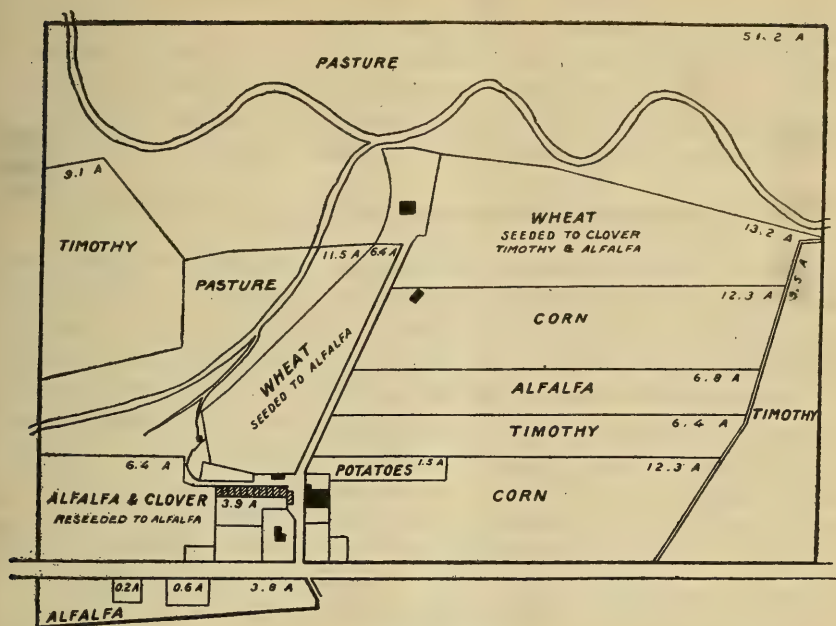
In order to show the use of the data given in the preceding tables, they are applied in the following pages to a particular farm located in the area of the survey.

DESCRIPTION OF FARM SELECTED.

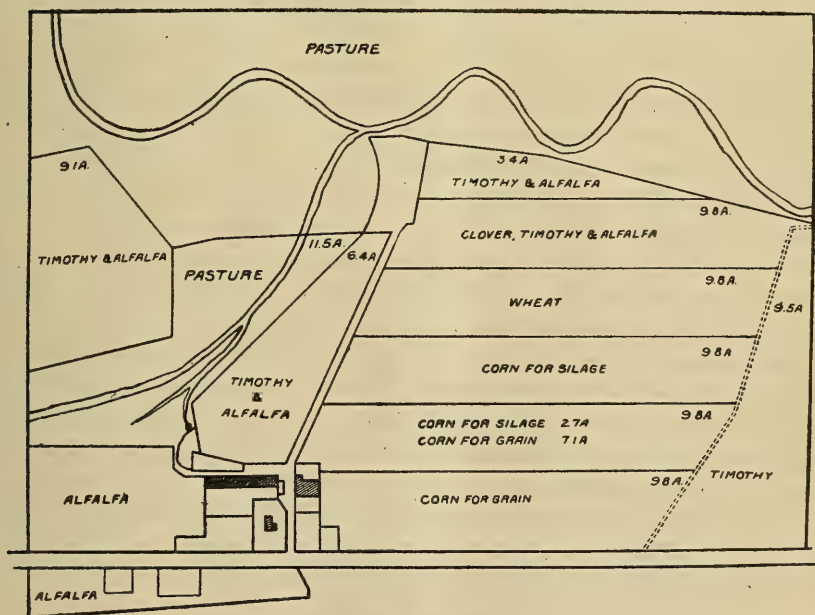
Map A (fig. 2) shows the field divisions, the acreage of each, the location of farm roads and buildings, and the crops grown on the farm selected. The farm contains about 155 acres, of which 63 acres, or about 40 per cent, are in permanent bluegrass pasture. This is badly cut by a stream, and therefore is not strictly tillable.

This farm in general is typical of the region, a large part of the income being derived from stock and stock products, mostly milk. The fact that alfalfa has been successfully grown was considered in the selection of this farm, as the growing of this crop is rapidly increasing in this county.

Though the fields are unequally divided, roughly speaking, the following rotation has been practiced: (1) Corn for grain; (2) corn for silage; (3) wheat; (4) clover and timothy; (5) timothy, one and sometimes two years. Recently alfalfa, 5 to 6 quarts per acre, has been added to the grass mixture. This requires that the grass be cut



A.—Original plan of farm.



B.—Revised plan of farm.

FIG. 2.—Old farm layout compared with the new.

before the timothy heads have blossomed in order to harvest the alfalfa before it matures. In favorable seasons a second cutting of alfalfa mostly is harvested. Small or irregular fields are put into alfalfa. The area devoted to corn and hay is somewhat above the proportion of these crops on the average dairy farm in this region.¹ This is due to the large number of live stock kept.

DETERMINING LABOR REQUIREMENTS OF OLD SYSTEM.

Table X gives the amount of man and horse labor required per acre for each month for the six crops grown on this farm. It is based upon the crew and work units as given in Tables III to IX, and also on the outline of the hours of labor required for the different operations. To find the total amount of labor required for any cropping system, multiply the figures given per acre in the above table by the number of acres of each crop to be grown. Assuming the acreage as given in map A (fig. 2), the total amount of man and horse labor on this farm will be distributed as shown in Table XI.

Figure 3 (A) is a graphic illustration of the time available and work to be done as given in Table XI. The area below the dotted line represents the available time each month for two men and a team of two horses and the shaded area the work that must be done. This chart shows the man-labor fairly well distributed in spring and early summer but not in late summer and fall. The increase of man-labor in June is due to the harvesting of the first crop of alfalfa and clover, and alfalfa and timothy mixture, which extends over into July. The increase of man-labor in July is due to the harvesting of wheat, the hauling of manure, and preliminary preparation of the ground for alfalfa and other new seedings, and in September to the extra labor required for cutting silage corn and corn harvested for grain.

The horse-labor also is distributed unevenly, requiring much more in July and August than during any other part of the season. This is largely due to the fact that 12.8 acres of alfalfa and 13.2 acres of clover and timothy were prepared and seeded at this time, in addition to the cutting of clover and timothy for hay, second cutting of alfalfa, and the harvesting of 19.6 acres of wheat. This amount of July and August work is a little unusual for this farm, as it happened that 6.4 acres of clover, alfalfa, and timothy required reseeding, and that about one-half more wheat was harvested than was seeded for the next year. When the fields are unequally divided, the amount of labor will always vary thus from year to year.

¹ See U. S. Dept. Bulletin No. 341, "Farm Management Practice in Chester County, Pa."

TABLE X.—Field, labor requirements for different crops per acre as shown in Tables III to IX.

Crop or operation.	February.		March.		April.		May.		June.		July.		August.		September.		October.		November.	
	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.
Corn for grain.....					8.4	21.0	5.4	10.2	4.4	9.1					14.0		25.2	10.2	11.9	11.9
Corn for silage.....					5.5	11.0	8.3	20.2	4.4	9.1					35.0					
Potatoes.....					22.9	27.3	5.6	11.2	4.8	8.8	0.4	0.4	7.1	3.7	21.5	11.3	21.3	16.6		
Oats.....	11.9	11.9	1.1	2.2	10.0	20.0					6.4	2.7	3.4	3.4			7.8	20.0		
Wheat, including clover and timothy seeding.....					0.5						3.2	6.6	7.1	14.1						
Clover and timothy seeding in August.....											8.2	7.6								
Harvesting clover and timothy.....									5.0	4.7	5.1	4.7								
Alfalfa seeding.....									12.1	12.2	10.0	17.7	20.1	35.5						
Harvesting alfalfa, 3 cuttings.....									2.7		8.2	8.2	6.2	6.2	2.0	2.0				
Top-dressing and harrowing alfalfa sod.....										5.4										

TABLE XI.—Field labor requirements for 87.7 crop acres.

Crop or operation.	February.		March.		April.		May.		June.		July.		August.		September.		October.		November.	
	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.
Corn for grain, 12.3 acres.....					103	258	66	125	54	112					172		310	125	146	146
Corn for silage, 12.3 acres.....					68	135	102	248	54	112					430	246				
Potatoes, 1.5 acres.....	18	18	2	4	34	41	8	16	7	13	1	1	11	5	32	17	32	25		
Clover, timothy, and alfalfa mixture—harvesting hay, 31.4 acres.....									157	147	160	147								
Alfalfa, 10.8 acres—harvesting hay.....									128	129	87	87	66	66	21	21				
Wheat harvesting, 19.6 acres.....											125	129								
Alfalfa seeding, 12.8 acres.....											128	227	257	454						
Clover and timothy seeding, 13.2 acres.....											42	100	94	186						
Wheat seeding, 12.3 acres.....															76	152	96	246		
Total.....	18	18	148	150	205	434	176	389	400	513	543	691	428	711	731	437	438	396	146	146

When a type of general farming is followed which carries no animals except work stock, the horse-labor should run much more evenly than on a dairy farm. Data which have been obtained from these

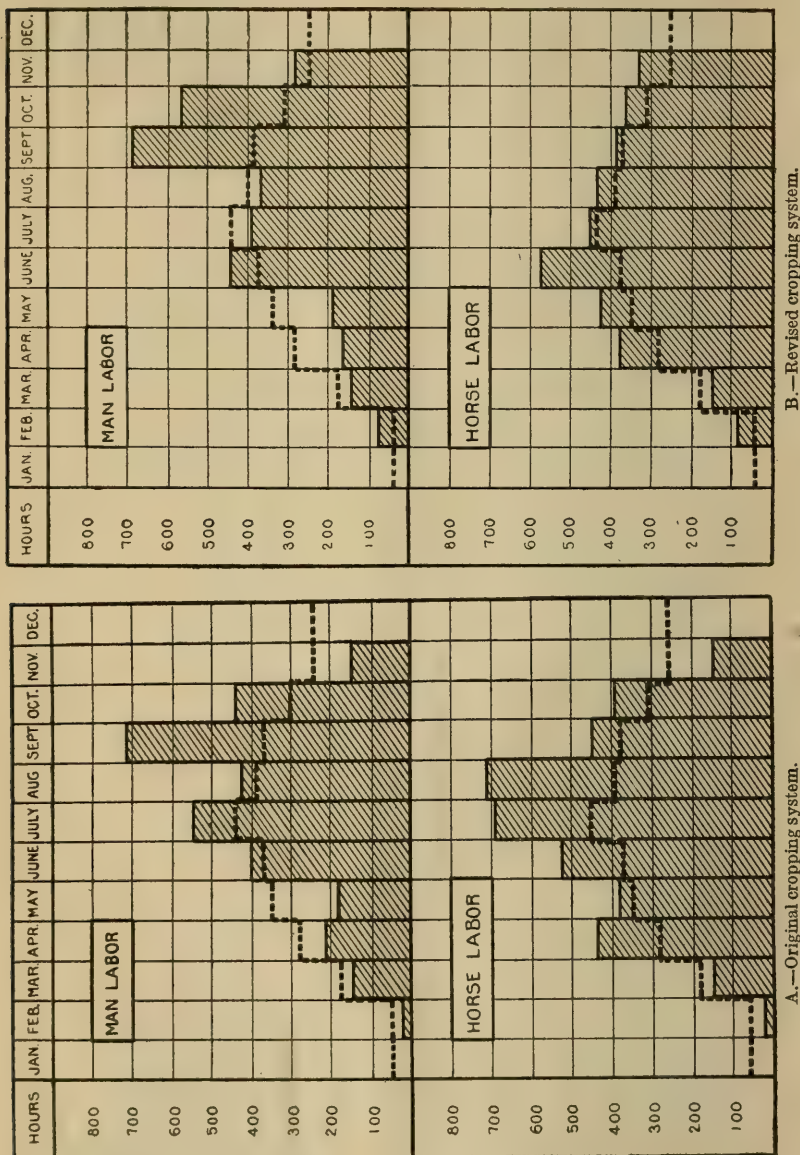


Fig. 3.—Available time for two men and one 2-horse team compared with work that must be done (dotted line, available time; shaded area, work to be done).

farmers show that on a dairy farm, as a rule, at least 30 to 40 per cent of the total labor required will be work other than field operations. While it may appear that the man and horse labor is not well employed on this farm in April, May, and June, considerable labor always is

required at this season for repairs and improvements of fences, buildings, or implements, and the hauling of fertilizer, feed, and milk, which is not shown in this chart.

REPLANNING CROPPING SYSTEM.

After having studied this cropping system from the standpoint of labor, the next point is to consider whether or not the cropping system can be changed, either by rearranging the fields to establish a definite rotation, by rearranging the acreages of crops, or by the introduction of new crops to balance the months of very high labor requirement, so as to increase the net income of the farm. The effect on the income of the farmer is the primary point of view to be taken in replanning a farm, taking into consideration, of course, the maintenance of soil and equipment and the availability of labor. If extra horse or man labor can be obtained whenever necessary, a farmer may be justified in practically ignoring labor requirements and selecting those enterprises which are best adapted to the farm conditions.

The layout of the farm in question was studied with a view to such rearrangement and a 7-year rotation was established as follows:

1. Corn for grain.
2. Corn (for grain, 7.1 acres; for silo, 2.7 acres.)
3. Corn for the silo.
4. Wheat.
5. Clover, timothy, and alfalfa hay (2 cuttings).
6. Timothy and alfalfa hay (2 cuttings).
7. Timothy and alfalfa hay (mostly alfalfa).

In contemplating a change in the cropping system the rotation must conform to the general layout of the farm. There are often conditions which prevent the readjustment of fields in the manner desired. Moreover, it is desirable to make changes that will require the least expense. The rotation outlined in the revised plan of this farm is not a rotation generally recommended for the average Chester County farm, but is suggested because it is best adapted to the existing field arrangement. Under ordinary farm practice, with clover one year, followed by timothy for one or two years, three years of corn in succession might have an influence to decrease crop yields. On this farm, however, the influence of an alfalfa sod supplemented by an application of manure to the corn crop will tend to increase, rather than decrease, crop yields.

The principal crop area was divided into five fields of 9.8 acres each, a triangular field of 3.4 acres at the farther end of this tillable tract, and one field of 6.4 acres formerly in wheat seeded to alfalfa on the other side of the farm lane, making together 9.8 acres which

can be planted to the same crop. The seventh field to enter into the rotation will be the 9.1-acre field, separated from the pasture area. In addition to the rotation area, 10.2 acres can be kept permanently in alfalfa and 9.5 acres in timothy, reseeding any portion when necessary by first planting corn for the silo, following with wheat. The 9.5 acres of permanent timothy is a field that is irregularly shaped for cultivation, rather low, and best suited to this crop.

The periods of harvesting corn for grain, for plowing sod, and for hauling manure, have been varied (within the limits of possibility, however) from the outline given in Table X, in order to facilitate labor. It was found that by increasing the acreage of field corn, and decreasing the acreage of alfalfa, the crops could be handled with about the same amount of labor, but that this labor would be much more evenly distributed throughout the season.

Table XII gives the total amount of man and horse labor required under the revised system. Because of the increased acreage of corn, a part of the labor for harvesting this crop was carried over into November, and the figures for this month also include the manuring and plowing of 9.8 acres of sod land to be planted to corn for grain the next season. The balance of the corn land to be planted for grain will be manured in February and the area for silage manured in March.

The graphic illustration of the labor required in the replanned cropping system (fig. 3, B) shows a much more even seasonal distribution of horse labor. The greatest variation comes in June, which is due to the fact that the grass mixture contains alfalfa, which requires early harvesting. Because of the labor requirements in enterprises other than field crops, it is possible that four farm horses should be kept on this farm. By arranging the work and concentrating all efforts on the field crops during the month of June, it is probable that this harvesting can be done without hiring extra horse labor. When it is necessary to reseed the permanent alfalfa or timothy, the horse-labor for August will be greater than represented on the chart, but in no case greater than for June.

The man-labor requirements for September and October are much greater than for any other month. This condition is hard to change. It may be possible, however, to lower the amount of man labor in September by the use of a corn harvester, and this can be done without radically changing the horse-labor distribution. It is comparatively easy, furthermore, to hire extra labor in husking corn. If the farm help is needed in thrashing wheat, this operation could more advantageously be done in the month of August.

TABLE XII.—Field labor requirements (revised).

Crop or operation.	February.		March.		April.		May.		June.		July.		August.		September.		October.		November.	
	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.	Man-hours.	Horse-hours.
Corn for grain, 16.9 acres.	84	84																		
Corn for silage, 12.5 acres.																				
Wheat, 9.8 acres.																				
Timothy, clover, and alfalfa, first cutting, 38.3 acres.																				
Clover and alfalfa, second cutting, 28.8 acres.																				
Alfalfa, three cuttings, 10.2 acres.																				
Top-dressing timothy with manure, 9.5 acres.																				
Top-dressing alfalfa with fertilizer, 10.2 acres.																				
Clover, timothy, and alfalfa seeding, 9.8 acres.																				
Total.....	84	84	149	149	157	385	194	424	445	572	400	458	369	437	688	392	569	368	284	338

COMPARATIVE LABOR REQUIREMENTS.

The calculated cost of man and horse labor required in field operations for the cropping systems illustrated in figure 2 from March to November, inclusive, is as shown in Table XIII.

TABLE XIII.—*Comparative labor requirements.*

ORIGINAL CROPPING SYSTEMS.

Crop or operation.	Acres.	Man labor.	Horse labor.	Total.
Corn for grain.....	12.3	\$119.33	\$84.42	\$203.75
Corn for silage.....	12.3	112.10	97.69	209.79
Potatoes.....	1.5	20.29	15.41	35.70
Harvesting mixed hay ¹	31.4	44.40	32.46	76.86
Harvesting alfalfa hay.....	10.6	42.29	33.35	75.64
Harvesting wheat.....	19.6	17.56	14.23	31.79
Seeding wheat.....	12.3	24.11	43.84	67.95
Seeding alfalfa.....	12.8	53.94	74.91	128.85
Seeding clover, timothy, and alfalfa.....	13.2	19.04	31.51	50.55
Total.....		453.06	427.82	880.88

REVISED CROPPING SYSTEMS.

Corn for grain.....	16.9	\$163.96	\$115.99	\$279.95
Corn for silage.....	12.5	113.93	99.27	213.20
Harvesting mixed hay ¹	38.3	87.22	65.56	152.78
Harvesting alfalfa hay.....	10.2	40.70	32.09	72.79
Harvesting wheat.....	9.8	8.78	7.11	15.89
Seeding wheat.....	9.8	19.21	34.93	54.14
Seeding clover, timothy, and alfalfa.....	9.8	14.13	23.39	37.52
Topdressing timothy with manure.....	9.5	15.82	12.43	28.25
Topdressing alfalfa with fertilizer.....	10.2	3.92	6.16	10.08
Total.....		467.67	396.93	864.60

¹ A second crop, mostly alfalfa, on 28.8 acres will be cut the second time.

In the preceding table it is obvious that the changes in the cropping system can be made without increasing the cost of labor. The rearrangement has increased the amount of man labor, but on the other hand decreased the amount of horse labor. The total cost of horse labor was decreased to the amount of \$30.89, and the total labor, \$16.28.

COMPARATIVE RETURNS.

A comparison of the gross incomes from crops in the two cropping systems will give further light on the relative desirability of the two systems. The values assumed, based on the average yield of crops obtained by successful farmers in the locality and on market prices at the farm, are shown in Table XIV.

Thus it will be seen that the revised system brings a gross income of more than \$550 over that of the first system, while the total labor bill is at the same time reduced from \$880.88 to \$864.60.¹ The saving in this case is not so much in amount of labor as in its utilization.

¹ It is impossible in this bulletin to work out all the factors which enter into the total cost of the crop. There is so much variation in the previous management of the soil, in the soil conditions in respect to the amounts of fertilizer used, the rental charge for land, the equipment charge and overhead charges, that these costs should be worked out for each individual case.

TABLE XIV.—*Comparative returns.*

Crop.	Yield per acre.	Price per unit.	Gross income.	
			First system	Second system.
Corn for grain.....	70 bushels.....	\$0.60	\$516.60	\$709.80
Corn for silage.....	12 tons.....	4.00	590.40	600.00
Corn stover.....	2 tons.....	4.00	98.40	135.20
Potatoes.....	125 bushels.....	.60	112.20	
Mixed hay, first cutting.....	2 tons.....	16.00	1,004.80	1,225.60
Mixed hay, second cutting.....	1 ton.....	18.00		518.40
Alfalfa, 3 cuttings.....	3.5 tons.....	18.00	667.80	642.60
Wheat.....	25 bushels.....	.95	465.50	232.75
Wheat straw.....	1 ton.....	5.00	98.00	49.00
Total.....			3,553.70	4,113.35

CONCLUSION.

It is plain to be seen from this comparison that the consideration of the labor requirements of a farm in working out any plan of farm organization and carrying the plan into operation is not the least important factor in farm management. Too many times this matter has received very little attention, particularly with farmers with but little farm experience. A study of these questions gives a basis of increasing labor efficiency. The real object of this bulletin is not to show what the farmers in Chester County are doing, but to illustrate principles which may be applied anywhere in devising a cropping system for efficient utilization of labor.

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VALIDITY OF THE SURVEY METHOD OF RESEARCH.

By W. J. SPILLMAN, *Chief, Office of Farm Management.*

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INTRODUCTION.

The distinguishing feature of farm-management investigations is the application of the inductive method of reasoning to farm practice. In practically all farming communities can be found examples of successful and of unsuccessful farms. It is assumed that a careful analysis of the methods and business system of a large number of farmers, all working under essentially similar soil, climatic, and economic conditions, may be made to reveal the reasons for the success of one and the failure of another. The essential difference between the farm-management method and the laboratory method of investigation lies in the fact that the laboratory investigator varies his causes and studies the resulting variation in the effects produced. The farm-management investigator has his experimental results already produced for him. He merely collects the results of farm experience, arranges them in such manner as to display the variations of a causal factor, and then studies the resulting variations in the effects produced. Suppose, for example, it is desired to know what degree of soil fertility will result in the greatest profit to the farmer under the conditions prevailing in a given locality. Having analyzed the business of a large number of farms in the locality, the farms are first grouped on the basis of their yields per acre, with enough farms in each group to give reliable averages. The average profit made by the farms in each group is then determined. Table I

shows this relation for a group of 378 farms in southeastern Pennsylvania. The results indicate that under the conditions prevailing in this locality, and with the methods practiced by local farmers, the point of diminishing returns is reached when the yield on a given farm reaches about 40 per cent above the general average of the community. Yields higher than this appear to be obtained at an expense greater than the increase in income due to the increased yields. The figures would naturally differ for different regions.

TABLE I.—*Relation of crop yield to labor income.*

	Groups of farms based on yield per acre.				
	84 and less.	85-99	100-114	115-139	140 and over.
Average yields expressed in percentage of the community average.....					
Average labor income expressed in percentage of the community average.....	49	74	108	153	130

HOW FARM RECORDS ARE OBTAINED.

Knowledge of the details of farm practice and of the results arising from this practice may be obtained in two ways. First, careful records may be kept of the details of the farm work and the business transactions of the farmer. Second, such details may be obtained by interviewing farmers who give them as accurately as may be from memory, or from such desultory records as may have been made of the farm operations. The first of these methods involves years of labor and enormous expense; the second gives an enormous amount of data in a short while and at a nominal expense. The question is as to the relative accuracy of these two methods.

When farm management investigations first began it was supposed that the only way to get at the facts of farm practice with a degree of accuracy sufficient for investigational purposes was by means of carefully made records. Accordingly, cost-accounting records were begun on a large number of farms. It was soon perceived, however, that the cost of such records and the time required for their accumulation were serious obstacles. Furthermore, practice differs so widely in different regions, on different farms in the same locality, and even on the same farm from year to year, that it would be an interminable task to collect sufficient data in this manner to solve the numerous problems which the study of farm practice had revealed. Because of the amount of time involved the results would frequently be out of date before the work could be finished. Finally it was decided to give the second method a trial. At first many students of farm management had misgivings as to the validity of data obtained from farmers who keep few or no records. Accordingly, in order to test this point a number of investigations were un-

dertaken. These were of necessity limited to data which were either already available in reliable records or of which such records could be secured by instituting a system of cost accounting. The results of these investigations are given below.

INVESTIGATIONS BY F. E. ROBERTSON.

Where a community of farmers sell all their milk to local creameries it is possible to get an accurate record from the creameries of the amount of milk sold by each patron and the receipts for the same. In a dairy community in southern New Hampshire 135 farmers were found who sold all their milk to local creameries. These farmers were asked to give an estimate of the amount received for milk during the preceding year. Many of them at first professed to be unable to do this, but a little questioning as to the number of cows kept, the amount of the monthly milk check, etc., finally elicited an estimate from each of them. Later the precise amounts were copied from the books at the creameries. The results are shown in Table II. The error in these estimates, taking all farms together, was \$346, or slightly less than one-third of 1 per cent of the total.

TABLE II.—*Comparison of farmers' estimates and creamery records of annual receipts for milk on 135 New Hampshire dairy farms.*

Estimated value of milk sold, all farms-----	\$106, 183
Actual value of milk sold, all farms-----	105, 837
Error in estimates-----	346

Before this investigation was finished it occurred to the investigator to include also the amount of milk sold. Accordingly, the remaining farmers, 79 in number, were asked to estimate this item. These farmers were in the habit of thinking in terms of dollars and cents but not in terms of pounds or gallons of milk. They found it more difficult to estimate quantity than value of milk sold. The results are given in Table III. In this case the error in the total for all the farms was nine-tenths of 1 per cent.

TABLE III.—*Comparison of farmers' estimates and creamery records of pounds of milk sold annually on 79 New Hampshire farms.*

Estimated pounds of milk sold, all farms-----	3, 518, 816
Actual pounds of milk sold, all farms-----	3, 487, 320
Error in estimates (pounds)-----	31, 496

INVESTIGATIONS BY A. D. McNAIR.

An investigation was made at Belton, S. C., of the pounds of seed cotton per bale from estimates of seven farmers and from gin records of 400 bales. The average for the 400 bales, according to the gin records, was 1,362 pounds of seed cotton per bale. The average of

the seven farmers' estimates was 1,369 pounds, the difference being about one-half of 1 per cent of the gin record.

The same investigator obtained the percentage of lint to seed cotton from gin records of 1,192 bales of cotton at Atkins, Ark., and from farmers' estimates on 151 bales in the same locality. According to the gin records, the average turnout of lint cotton was 32.5 per cent; the average of the farmers' estimates was 33.1 per cent. He made a similar investigation at Dermott, Ark., the gin results being 31.75 per cent (on 907 bales) and the farmers' estimates being 31.2 per cent (on 65 bales).

Records kept on 15 farms in an Arkansas community on the amount of cotton picked per day per man gave an average of 140.4 pounds. The average of the estimates of 50 farmers in the same locality was 140.3 pounds per day.

On 23 plantations in Coahoma County, Miss., on which were 9,326 acres of share croppers' cotton and 1,509 acres of share croppers' corn, the number of days of labor on these crops as shown by planters' estimates was 129,347. Each planter also estimated the number of days of "outside labor" performed, and this amounted to 14,018, or a grand total 143,365 days of labor for the share croppers and their families. On the same plantations each owner was asked to estimate the gross yearly value of the labor of the share croppers and their families, and the total for the 23 plantations was \$144,007. This sum of money is equal to a daily wage of \$1.004 for each of the 143,365 days of labor performed, which is a close approximation to the current wage of \$1 per day.

From the above data it appears that in the case of important items of the farmer's business he has knowledge which is quite accurate. Matters of less importance are usually not kept in mind so accurately. In the matter of the amount of labor done in producing a crop, which involves a knowledge of an average day's work at plowing, harrowing, seeding, cultivating, etc., the farmer's knowledge is based on experience usually covering many years, and the answers he gives to such questions are averages rather than figures applicable to any one year. Because of differences in the preceding crop, amount of rainfall from year to year, variations in temperature, etc., the work done on an acre of corn, for instance, may in any one year depart quite widely from the average. It is therefore impossible to test adequately the accuracy of the farmer's estimates of items of this character by comparison with actual records for any one year.

In order to show the variations that may occur between estimates based on many years' experience and accurate records for a single season, the following data relating to a group of 29 farms at Conway, Ark., are given. Each of these farmers was asked to estimate the

amount of man and horse labor required by an acre of cotton and an acre of corn, in both cases up to the time the cultivation of the crop is finished. The questions asked the farmer related not to the total amount of this labor but to the various operations usually performed and rate of work per day for each operation. That is, the questions were asked in the terms in which the farmer thinks. Later these same farmers were induced to keep accurate records of all the labor on their farms for a year. Table IV shows the results in comparison. Because of the variation from year to year of the actual amount of work done per acre on a given crop even on the same farm it is impossible to tell whether the actual work done during the season for which records were made on these farms is more accurate than the farmers' estimates. In any case the differences are seen to be relatively small when compared, for instance, with the differences in yield on duplicate plots in field experiments on the yield of crops.

TABLE IV.—*Comparison of 29 farmers' estimates with actual records for a single season of labor on cotton and corn to "laying by."*

Crop.	Man-days per acre.		Horse-days per acre.	
	Estimates.	Records.	Estimates.	Records.
Cotton.....	10.14	9.80	5.76	6.05
Corn.....	4.44	4.78	5.22	6.39

INVESTIGATIONS BY M. B. OATES.

Investigations of a similar nature were conducted in northwestern Louisiana. The results are given in Table V. The figures given are averages of 10 records and 11 estimates on cotton, 13 records and 13 estimates on corn, and 11 records and 10 estimates on peanuts. Ordinarily these numbers are too small to give reliable averages, yet the agreement between estimates and records is fairly satisfactory.

TABLE V.—*Comparison of records and estimates of man and horse labor on cotton, corn, and peanuts in Louisiana.*

Crop.	Man hours per acre.		Horse hours per acre.	
	Estimates.	Records.	Estimates.	Records.
Cotton.....	47.0	47.7	34.9	34.4
Corn.....	32.3	27.2	38.1	33.1
Peanuts.....	23.1	29.4	30.2	30.0

Estimates were also secured from 10 farmers of the number of days available for field work during the year. This number naturally varies with the character of the weather from year to year. Later

these same farmers kept records of the actual days available for such work on their farms for a year. Table VI gives a comparison of the estimate and the record on each of the 10 farms.

TABLE VI.—*Days per year available for field work.*

Farm No.....	1	2	3	4	5	6	7	8	9	10
By record.....	225	208	220	215	203	207	205	202	212	218
By estimate.....	221	203	216	221	212	182	203	212	216	206

The average of the 10 estimates is 209 days and of the 10 records 212 days, a difference of only $1\frac{1}{2}$ per cent of the total. Considering the fact that the quantity here under consideration actually varies considerably from year to year and that the records are for a single year, the agreement between the estimates and the records must be regarded as very satisfactory.

INVESTIGATIONS BY C. M. HENNIS.

In cooperation with the North Dakota Experiment Station the Office of Farm Management secured the data given in Table VII.

TABLE VII.—*Acres plowed per day.*

Number of horses.	Records.		Estimates.	
	Number of records.	Average.	Number of estimates.	Average.
3	15	<i>Acres.</i> 2.81	1	2.73
4	32	3.83	16	4.26
5	60	5.02	37	5.17
6	15	5.55	10	5.61

When it is remembered that the numbers averaged are in most cases very small and that the farmers making the records were not the same as those giving the estimates, but were located in the same general region, it must be admitted that it is possible to get just about as reliable results from farmers' estimates as it is from the most careful records provided the questions asked the farmer are within the range of his experience and thinking and provided the number of estimates is large enough to permit the proper working of the law of averages.

CASE OF A GEORGIA FARM.

In a farm management survey it happened that one enumerator obtained the record of a certain farm from the overseer at the farm, while another enumerator obtained the record of the same farm from the manager at his office in town. In both cases the record was given

from memory. The record from the manager gave a labor income of \$3,688, that from the overseer \$3,656, a difference of \$32, which is less than 1 per cent of the quantity involved. It should be remembered that records of this kind are used only in averages, so that errors in them are for the most part eliminated by the law of averages. (See p. 9.)

ACCURACY OF THE FARMER'S KNOWLEDGE.

The opinion prevails quite widely, even among farmers themselves, that the average farmer knows very little of the details of his business. The results given in the foregoing pages indicate that this opinion is not consistent with facts. During the past decade the Office of Farm Management has analyzed the business of nearly 20,000 farms. The experience gained in this work indicates that the average farmer does know the details of his business with a fair degree of accuracy, the discrepancy in his knowledge being relatively small in the case of the larger and more important items, but increasing as the importance of the items decreases. One reason for this is the fact that in a year's business on the average farm there are relatively few business transactions, most of them being fairly large items. The principal product of the farm is, in many cases, disposed of in a single sale, and the farmer remembers the details of this sale quite accurately until the corresponding figures for a new year replace them in his mind. In many other cases a product, such as eggs, milk, etc., is sold in fairly regular quantities from month to month, and the farmer remembers with a fair degree of accuracy the usual monthly income from such sales, as well as the variations in this income.

But though the farmer does know fairly well the details of his business, he is not always aware of this fact; and it requires no slight skill on the part of the investigator to reduce his questions to the terms in which the farmer carries the information in his head. Unless this is done, the answers given by the farmer are mere guesses and are of small value. Thus, if we ask a farmer how much profit he made on a certain field of corn he will usually not even hazard a guess at the answer, because he realizes he does not know; but if we analyze the cost and income from this field into its elements we find the farmer has very definite knowledge of these elements. He knows the operations, such as plowing, harrowing, planting, etc., done in raising the crop. He knows the amount and value of the fertilizers applied. He knows how much corn was secured and its market value. The trouble is not that the farmer does not know the facts necessary to arrive at the profit made from the field, for he does know them; but he does not know how to use these facts in calculating the profit, because his knowledge of cost accounting methods is meager. The

investigator, if he is competent, supplies the deficiency in the farmer's knowledge of bookkeeping, and together the two of them are able to arrive at an approximately correct solution of the problem.

Similarly with the profits from the entire farm. The farmer knows the facts necessary to calculate these profits, even though he may not know how to make the calculations.

It should also be remembered that the farmer's less accurate memory for small details is not a matter of great importance, for the smaller the item the less influence an error in it has on the final result.

ACCURACY OF COST-ACCOUNTING METHODS.

Those having even the most elementary knowledge of the principles of cost accounting are aware that such work always involves estimates, no matter how accurately it may be done, and these estimates not infrequently constitute an important proportion of the cost. Consider, for instance, the cost of a day of horse labor. This is the annual cost of keeping the horse divided by the number of days' work the horse does in the year. It is possible to arrive at a fairly accurate valuation of the feed the horse consumes and of the man labor required in caring for the horse, though the latter item itself is based partly on estimates (especially of the cost of the man's keep). Even then the variation in feeding practice from farm to farm and in the eating capacity of individual animals make the actual cost of feed a highly variable quantity, so that a single so-called "accurate" record is of little, if any, more value than an intelligent estimate of an experienced horseman. Another item in the cost of keeping the horse is interest on investment. To arrive at this we must estimate the market value of the animal. Depreciation is also an important element. In arriving at this we must not only assume a value for the horse, but we must make a guess at how long he will last. Barn rent is another item. To arrive at this we must estimate the value of the barn, the length of time it will last, the cost of future repairs, and the relative value of the space occupied by the horse, as compared to that used as a shelter for machinery, etc. We must also estimate the cost of harness required in order that the horse may do its work. The animal must also be credited with the value of his manure, another estimate.

The above facts suffice to show that on the farm even cost accounting is at best largely a matter of estimates. It is merely a question of the dependability of the estimates. It has been shown above that in matters in which farmers have had extended experience their estimates are so sufficiently reliable that when large numbers of them are averaged the results possess a very satisfactory degree of accuracy. However, it is not possible to overestimate the importance of

making questions submitted to farmers conform to the terms in which the farmer's knowledge exists. When this is done a proper study of data furnished by farmers may reveal numerous important facts never suspected either by the farmer or his questioner. For instance, if in the farm-management survey made some years ago in Lenawee County, Mich., the farmer had been asked directly what the manure of a horse or cow was worth to him, he probably would not have hazarded a reply. If he had it would have been little more than a guess, not an estimate. But when the question was broken up into its elements and he was asked to state the acreage and yields of his various crops, the prices at which his products were sold, the number and kinds of animals kept on the place, he answered readily enough. By taking these data from many farms and comparing those having relatively little stock with those having many, the actual increment in crop values due to the manure of a single animal was easily calculated.¹

LAW OF ERROR.

The law of error, frequently called the law of averages, may be stated in many different ways. Perhaps as comprehensive a statement of it as any is this: "Errors of measurement or observation tend, in the absence of 'bias,' to group themselves about the true value of the quantity measured in such manner as to eliminate each other in the final average."

The manner in which such errors group themselves about the true average will be discussed in some detail a little later.

Absolute accuracy is not obtainable in any kind of measurements. In any case it is merely a question of degree of accuracy.

The accuracy of any average depends on three things. First, and most important of all, is freedom from "bias"; that is, entire absence of any tendency to make each measurement too high or too low. In general, we have found bias singularly absent in practically all our field studies of farm practice. It is true that some farmers deliberately overestimate, but fortunately there seem to be about as many who deliberately underestimate. These over and under estimates tend to cancel each other and thus to reduce their effect on the resulting averages.

Second in importance is the number of items on which an average depends. The larger the number the more reliable the average. The reason for this lies in the fact that when a number of items is averaged the larger the number the better the chance that any error will be canceled by a similar error in the opposite direction.

Since no measurement of any kind is absolutely accurate, every measurement represents an error of greater or less magnitude.

¹ See Dept. Agr. Bul. 341, Table LX, p. 98.

Abundant study of the law of error has shown that large errors occur less often than small ones, and if bias is absent plus errors of any magnitude occur just about as often as minus errors of similar magnitude. This is well illustrated in Table VIII, which shows the distribution of errors in 354 separate measurements of an area.

TABLE VIII.—*Distribution of errors.*

Magnitude of error.	Number of plus errors.	Number of minus errors.
0 to 0.3.....	89	93
.31 to .6.....	51	55
.61 to .9.....	26	22
.91 to 1.2.....	8	8
1.21 to 1.5.....	2	0
Total number	176	+178=354

In these measurements there were in all 176 plus and 178 minus errors. Furthermore, of the errors of any given magnitude there are about as many plus as minus.

In so far as we have been able to test the matter, the errors arising in securing data from farm experience distribute themselves about the true value in approximately the manner above illustrated. It is therefore possible, by securing large numbers of estimates, to get averages of a very satisfactory degree of accuracy.

The third factor governing the accuracy of an average is the accuracy of the individual items averaged. Inaccuracies in these items, if bias is absent, tend to eliminate each other because of the manner in which errors group themselves about the true mean, provided the number of items is large enough. For this reason inaccuracies in the original measurements are less important than either absence of bias or number of items averaged.

Pearl and others have shown by actual count that an average is more accurate than the data on which it is based. This fact has indeed long been known. The relation of the accuracy of an average to that of the items averaged is given by the well-known formula

$E = \frac{e}{\sqrt{n}}$, where E is the probable error of the mean, e the probable error of a single observation, and n the number of observations averaged. Thus it might be said that an average based on, say, 40 observations of a variable quantity is twice as reliable as one based on 10, and an average based on 100 observations is 10 times as trustworthy as a single observation. Even if the probable error of the individual estimates is as much as 25 per cent, the probable error of the average of 100 such estimates is only $2\frac{1}{2}$ per cent. Hence, even if the farmer's knowledge of the details of his business were even less definite than experience has shown it to be it would still be

possible to get fairly reliable results by securing large numbers of estimates and using only averages of them. This principle is taken advantage of in the study of farm practice, and there is reason to believe that, within the proper limits of use of the results obtained, studies of this kind are entitled to at least as much consideration from the standpoint of accuracy as are those involving experimental work conducted under the most favorable field conditions. Indeed it is believed that when carefully conducted by those properly trained both in the collection of data and in the interpretation of these data, the results of such studies approach in accuracy those obtained in laboratory investigations.

The so-called law of averages is merely one manifestation of the laws of probability, or chance. It is not feasible here to discuss these laws in detail. They are fully treated in standard texts, with which every experimentalist should be familiar. In fact, the interpretation of experimental results which does not take into account the law of error is nearly as apt to be wrong as it is to be right. A little consideration will show that in a highly variable quantity, such as the yield of a given plot treated in a given way, six duplicate plots is far too small a number to insure with any degree of certainty that the action of the law of averages will eliminate the departures from the true average. In general, the average of six such yields, no matter how accurately each yield is measured, is far less reliable than would be the average of 60 estimates of farmers based on years of experience with a given field. Sixty such estimates give a chance for the law of averages to eliminate a large proportion of the errors in the individual estimates, and these errors are in general no larger than those in plot yields, no matter how accurately these yields are measured.

While we may not here consider the laws of chance in detail, a few illustrations of them may serve to show that such laws actually exist.

In flipping a penny it is an even chance whether heads or tails turn up at any particular throw. Now, it has been proven by abundant experiment that as the number of times the penny is thrown increases, the tendency for the total number of heads to equal the total number of tails increases. In other words, where the chance is even the event will, on the average, turn out in one of two possible ways as often as it does in the other.

In throwing a single die there are six possible results, all equally likely to occur. There is thus a tendency, when a die is thrown many times, for any one of the six faces to turn up one time in six on the average.

An excellent illustration of the workings of the laws of chance was recently found in tabulating the replies to a circular letter sent out

by the Office of Farm Management. The latter contained a list of implements, and the farmers to whom it was sent were asked to state in connection with each item whether he owned the implement named and whether he recommended its purchase by farmers. The particular tabulation with which we are concerned here included only those farmers recommending the purchase, the object being to ascertain what proportion of them had acted on their own recommendations. The blanks used in tabulating the replies had spaces for entering 700 replies relating to a particular implement. The replies when entered in several cases filled two or more pages of the blank. After the answers had all been recorded, it was noticed that where the replies relating to a particular implement filled more than one page, the proportion of farmers owning the implement among those recommending its purchase was nearly the same on each separate page. Table IX has been constructed to show this interesting operation of the laws of chance. Take, for instance, the figures relating to the emery wheel (see Table IX). Of the 1,400 replies relating to it 976 were from farmers owning this implement. It happened that in tabulating the replies, exactly half of the owners were recorded on each of the two pages. Since this fact was not noticed until the tabulations had been completed, and since the replies were handled without any thought of the matter here under discussion, this perfectly even distribution of the 976 owners between the two arbitrary groups of 700 can only be ascribed to pure chance, or as nearly pure chance as can be imagined. It was an even chance whether any particular owner's reply should be recorded on the first page of the blank or on the second; hence half fell on one page and half on the other.

That this result is not wholly capricious but is really due to the operation of a law is shown by every other case where two full pages of the blank were filled. There are nine such cases in the table. In no case where an even chance existed does the number of owners recorded on a page exceed 52 per cent or fall below 48 per cent of the total number of owners on the two pages.

The figures relating to the set of stocks and dies are an excellent illustration of the importance of numbers in arriving at an average. The replies in this case filled slightly more than two pages. On the first page, containing 700 replies, 52.71 per cent were from farmers owning a set of stocks and dies. On the second page the percentage is 52.43, or practically the same. But on the third page, where there are only six replies, 83 $\frac{1}{3}$ per cent are from owners. Six is too small a number to give a reliable average in such a case.

In the case of most of the implements of the list there was one page of the tabulating blank only partially filled. In all these cases, excepting only the one just mentioned, the proportion of owners is

nearly the same as on the corresponding full pages. Thus, in the case of the drill press the third page contains only 44 replies, but the percentage of owners among them is nearly the same as on the preceding full page. Even here the number of replies is sufficient to permit the law of chance to make itself evident.

TABLE IX.—*Illustrating operation of law of chance.*

Implement.	Page No.	Number of farms having.	Percentage of owners on two pages.	Number of farms recommending.	Per cent of those recommending having.
Carborundum or emery wheel.....	1	488	50.00	700	69.71
	2	488	50.00	700	69.71
Set of stocks and dies.....	1	369	50.14	700	52.71
	2	367	49.86	700	52.43
	3	5	-----	6	-----
Gasoline blowtorch.....	1	205	-----	700	29.28
	2	105	-----	426	24.64
Wrecking tool.....	1	537	50.3	700	76.71
	2	532	49.7	700	76.00
	3	133	-----	180	73.88
Pinch bar.....	1	612	50.5	700	87.43
	2	598	49.5	700	85.43
	3	87	-----	104	83.65
Hack saw.....	1	478	51.5	700	68.28
	2	450	48.5	700	64.28
	3	38	-----	53	71.69
Small hoist.....	1	520	50.1	700	74.28
	2	519	49.9	700	74.14
	3	148	-----	220	67.27
Drill press, or breast drill.....	1	454	52.0	700	64.85
	2	420	48.0	700	60.00
	3	26	-----	44	59.09
Combination vise, drill, and anvil.....	1	370	-----	700	52.85
	2	345	-----	654	52.75
Combination pliers.....	1	638	50.15	700	91.14
	2	634	49.85	700	90.57
	3	190	-----	216	87.96
Expansion bit.....	1	349	-----	700	49.86
	2	296	-----	568	52.11
Combination bevel square.....	1	375	-----	700	53.57
	2	274	-----	494	55.46
Heavy shears, or tinner's snips.....	1	448	51.32	700	64.00
	2	425	48.68	700	60.71
	3	53	-----	86	61.62

The fact that in each case it is page 1 that has the highest proportion of owners is of no significance, since the full pages were deliberately arranged in this order after the tabulation was completed, the original chance arrangement being thus lost.

MISTAKEN NOTIONS OF ACCURACY.

In the endeavor to find the average value of a variable quantity, such as annual rainfall, the yield per acre of a crop under given conditions, etc., there is such a thing as gross inaccuracy in the final result even where the individual measures are made with a high degree of precision. Suppose, for instance, it is desired to ascertain the average yield of winter wheat after summer fallow as compared with the yield after a preceding crop of small grain, under the soil and climatic conditions prevailing on a particular tract of uniform soil.

Suppose the actual average for summer fallowed land, as determined by the average of an indefinitely large number of trials extending over a series of years sufficient to give average climatic effects, is 30 bushels per acre and that in a particular experiment it is 20 bushels. Now there is in this latter figure an inherent error of 10 bushels, and this error can not be eliminated by any degree of accuracy in measuring the 20-bushel yield. The only way to eliminate errors of this kind is to get enough observations to allow the law of averages to operate on them; that is, to insure the elimination of errors in one direction by the occurrence of similar errors in the opposite direction.

The relatively small importance of accuracy in the items to be averaged as compared with the great importance of the number of these items is well illustrated by the following facts concerning rainfall at Penn Yan, N. Y. The annual precipitation at this station has been measured to the hundredth of an inch each year for a period of 60 years. The average of the 60 annual records is 29.113 inches. If instead of the actual rainfall for each year we use the nearest multiple of 10, thus recording 26.73 as 30, 23.87 as 20, and so on, we get an average of 28.667, which is in error 1.532 per cent, assuming 29.113 inches to be the true average. If now we divide the 60-year period into six periods of 10 years each, using the measurements to the hundredth of an inch, the averages of these six periods are in error to the extent of 3.24, 7.51, 2.95, 7.24, 2.94, and 3.52 per cent, respectively. That is, the 60-year average based on measurements made to the nearest multiple of 10 inches is more accurate than any one of the 10-year averages based on the most accurate measurements.

It is not intended here to convey the impression that accuracy in original data is a matter of small importance. Such accuracy is important. The main point to be made is that numbers of items to be averaged is still more important. Our studies lead to the conclusion that errors in the farmer's knowledge of the details of his business and of the work he does are in every way comparable to the departures from the true mean in field plot experimental work and that they distribute themselves about the true values in approximately the same manner. The fact that the survey method of investigation gives data sufficient to permit the law of averages to eliminate plus errors by the occurrence of similar minus errors while plot experiments ordinarily do not do this appears to justify the statement that the survey method is a more reliable means of arriving at those facts to which it is applicable than the field plot experimental method. It appears, in fact, to occupy a place intermediate between plot experiments on the one hand, where variations

in other factors than that under observation occur and are not adequately eliminated, and laboratory studies on the other hand, in which variations in other factors are largely prevented. These variations due to factors other than that studied do occur in using the survey method, but the amount of data obtained by this method is sufficient to permit the elimination of such variations by the operation of the law of averages. The fact that there is such unanimity in the conclusions of investigators using the survey method in all parts of the country is, of itself, evidence of the general validity and great utility of this method of research.

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CHARLES J. BRAND, Chief

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THE ORGANIZATION AND MANAGEMENT OF A FARMERS' MUTUAL FIRE INSURANCE COMPANY.

By V. N. VALGREN,
Investigator in Agricultural Insurance.

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INTRODUCTION.

Farmers' mutual fire insurance companies represent one of the most successful efforts at rural cooperation in the United States. Nearly 2,000 such companies are in existence, with a total amount of insurance in force exceeding $5\frac{1}{4}$ billion dollars. These companies are increasing rapidly in number and size. In some States of the Middle West fully three-fourths of all insurable farm property is now insured in the farmers' own companies. Organizations of this kind are found in every State except Florida, Mississippi, Louisiana, New Mexico, Arizona, and Nevada.

The organization of a farmers' mutual insurance company should be preceded by a certain amount of preparatory work. The legal

NOTE.—This bulletin is intended mainly for two classes of readers—those contemplating the organization of a farmers' mutual fire insurance company and those desiring to improve the methods and practices of an existing company. It aims to outline principles and methods developed by successful companies of this kind and to set forth the advanced ideas held by their officers, rather than to discuss the subject theoretically.

step of incorporation should not be taken until as large a percentage as possible of the substantial farmers in the community have been interested in the undertaking. Twenty-five States now provide in a separate chapter or division of their insurance laws for the incorporation of farmers' mutual fire insurance companies. In most of the other States it is possible to incorporate such companies under the insurance laws referring to fire insurance mutuals in general.

In any case the organizers are required to set forth in a formal paper, usually called articles of incorporation, the name of the proposed company, the location of its home office, the purpose of the organization, the business territory, the conditions of membership, a brief outline of the form of management proposed, and the conditions under which the various provisions outlined in the articles of incorporation may be altered or amended.

As soon as incorporation has been accomplished, a set of by-laws should be drawn up. If the articles of incorporation have described the nature and purpose of the organization in outline only, these same topics should be taken up fully in the by-laws. The machinery of management should be provided for and the conditions of insurance should be carefully stipulated. Detailed provisions regarding the routine of the business should be avoided, however, and considerable discretion in these matters should be left to the directors.

PURPOSE OF THE COMPANY.

The purpose of the organization should be stated clearly in the by-laws. It should be made evident that the object of the company is to safeguard its members against the burdens of disastrous losses, and that this is to be accomplished in the way that best serves the interests of the membership as a whole. This means that the company must promote energetically the elimination of preventable losses and distribute on an equitable basis the burden from those losses that it can not prevent.

The fact that a company of this kind is organized to prevent disastrous loss burdens does not mean that it should remove all burdens from the individuals who suffer losses of property. In all cases a reasonable part of the loss should be borne by the owner. It should be to his interest, above all others, to have his property remain in existence. If the entire loss is assumed by the company, it becomes a matter of no economic consequence to the owner whether his property is destroyed or not, and his strongest incentive to safeguard his property has been removed. There is also danger that a slight change of economic conditions may make it directly to his pecuniary advantage to have his property destroyed.

BUSINESS TERRITORY.

There has been a growing tendency in recent years on the part of legislatures to permit farmers' mutuals a wide business territory. Several States now permit companies of this kind to operate in the entire State. The tendency on the part of the companies to avail themselves of this privilege has been somewhat less marked. While it seems a natural ambition on the part of a farmers' mutual to desire to grow by extension of its territory as well as by adding to its risks within the territory already partly covered, there is danger that such ambition eventually will lead to less desirable results. One of the most important advantages that farmers' mutuals in general enjoy over larger companies is that of a community interest and a community pride in the success of the undertaking. Each member distinctly feels himself a part of the company. The individual member actively promotes the interests of the organization, is anxious to see all losers receive equal justice, and is usually satisfied with a reasonable settlement in case he himself suffers a loss. These conditions, together with the knowledge of one another's character and business affairs, tend to reduce the moral hazard to a minimum.

Even if a case of overinsurance in a farmers' mutual should occur in connection with property owned by an unscrupulous member who would be quite ready to occasion a loss to a large insurance company, located perhaps in a distant city, such a member is likely to hesitate to throw the loss upon his own neighbors. Thus the moral hazard is greatly reduced in the local farmers' mutual. Many of the local mutuals have done business for half a century or more without a single lawsuit. Such a record would rarely be possible except in a company founded on true cooperation and embodying the principle of community interest in some direct form. When risks are confined to a limited territory the saving in traveling expenses of directors, inspectors, and adjusters is also a large item.

MEMBERSHIP AND VOTING PRIVILEGE.

All persons whose applications for insurance have been accepted should be members of the company in every sense of the word. The character of the owner as well as the physical condition of the property should be considered before the application is approved. Once his application is accepted and a policy is issued to him, however, the new member should be treated in exactly the same way as the charter members.

Active cooperation of all the members should be the aim. The annual meeting should be well advertised and, if possible, made an interesting and significant community event. Occasionally a set of directors and officers are well satisfied to have the members neglect the annual meeting, thus leaving to those already in office all responsi-

bility, including the question of their own reelection. No intelligent or effective cooperation on the part of the membership can be expected under such circumstances and it is not conducive to true and continued progress, either in the improvement of risks or in the strengthening and expanding of the influence and reputation of the company. Members who know little or nothing about the organization to which they belong can hardly be expected to prove effective voluntary promoters of its interests.

A cooperative organization is logically an aggregation of persons rather than of wealth. While many plans of voting based on the amount of insurance carried are in use by the farmers' mutuals in different States, it is commonly conceded that the simple plan under which each member has one vote for each official to be elected, or for each measure to be passed upon, is best.

A somewhat stronger case is presented in favor of the right of a member to cumulate his vote upon less than the total number of directors to be elected. For instance, if three directors are to be chosen, each member is permitted three votes, which he may cast, one for each of three men, or two for one man and one for another, or all three for the same candidate. This plan is intended to give a reasonable representation to a minority faction, if such faction should exist. The plan is subject to the possibility of accident, however, unless it is combined with the very cumbersome preferential voting plan, and under certain circumstances it may make for minority control instead of for majority control with minority representation. Such an outcome is doubtless rather unlikely, but it is by no means impossible. Under the old plan of one vote for each of three candidates, the minority faction, if there be one, may be left unrepresented, but this is certainly less objectionable than to have the control of an organization turned over by mere chance to a minority.

A provision for votes by proxy, without proper safeguards, should be avoided. In a number of farmers' mutuals it has led to undesirable results. The vote of a member, as a rule at least, should be cast in person at the formal gathering of the membership, where the voter's own opinion can be expressed, and any such opinion based upon misunderstanding can be corrected. In a company with a limited business territory such a requirement can not be said to be unreasonable, so far as the average member is concerned. Individual cases may exist, of course, in which persons with sound and settled opinions in regard to the company's affairs find it difficult or even impossible to attend a given meeting. If it is thought desirable to provide for these exceptions, and if the laws of the State permit, voting by mail, under proper restrictions, may be provided for, or proxy voting may be permitted with a close limitation upon the number of proxy votes that may be assigned to any one member.

BOARD OF DIRECTORS.

The management of the company should be vested in a board of directors. The members of this board should be elected on such a plan that the term of office of only a part of the directors expires each year. Thus the board is a continuous body. The number of the directors should be sufficiently large to give representation to the different districts in the business territory, and to assure reasonably careful deliberation of questions of policy. If the number is too large, however, the transaction of business is likely to be unduly retarded by the profusion of opinions, and further, the per diem allowances for board meetings will become a needlessly heavy expense. Except where local conditions appear to require a certain grouping or distribution of the directors, nine members seem to form a board of convenient size. As nine is an odd number, there is no possibility of a deadlock when all members are present; at the same time a board of nine directors can be divided for election purposes into three groups or classes with the same number in each class.

If fewer than three classes are provided for, the group or class arrangement, which is intended to make the board a continuous body, becomes of little value, since the policy of the board may be entirely reversed by the new members chosen at a single election. The same danger may easily appear, even with three classes provided for, when the number of directors is either seven or five. With a board of seven members, for example, one class would consist of three directors and the other two classes of two directors each. In the year when the term of the three directors regularly expired a single accidental vacancy in either of the other two classes would cause a majority of the board to be elected at one meeting.

An opportunity to make a radical change in the management at a single meeting might be desirable if a large number of the members always attended the annual meetings. But where the attendance is usually small, as is frequently the case, one or two dissatisfied members may bring in a few friends and control the meeting. If all or a majority of the directors are to be elected at this meeting, the affairs of the company may thus be controlled for an entire year by men who represent a very small percentage of the membership. On the other hand, when only a third of the directors are to be elected at one meeting, the opportunity for such an action is removed. Even if one small group should control one meeting, there is ample opportunity for the membership in general to be informed of the situation before the next annual meeting, so that the election of another third of the directors by the few disaffected members is readily prevented.

While factional difficulties have been rare in the farmers' mutuals, they are by no means unknown.

Since the directorate represents the members, a vacancy in the board should theoretically be filled by election in the manner in which the position was originally filled. An extra meeting for the purpose of filling such a vacancy, however, involves considerable trouble and expense, and it is perhaps well to provide that the remaining members of the board shall fill the vacancy temporarily, the one so selected holding office only until the next regular meeting.

The board of directors, subject to the articles of incorporation and the by-laws, should have full and complete charge of the business of the company. The limitations upon its powers provided for in the by-laws should be such as affect the broader policies of the company only. Details of administration should be left in general to the discretion of the board. Without discretionary powers in these matters the directors are not in a position promptly to meet new conditions that may arise, nor can they properly be held responsible for the efficient management of the company's affairs. All officers and employees should be elected or appointed by the board or its representatives and should hold office only so long as they discharge their duties faithfully and efficiently. The compensation of all such officers and employees should be fixed by the board. Only the compensation of the directors themselves should be stipulated in the by-laws.

OFFICERS AND COMMITTEES.

There are good reasons why the regular officers should generally be elected by the board from their own number. It is probable that the members will have elected as directors the men in the community who are best qualified to transact the company's business for them. Hence to insist that the officers be elected from outside the board may deprive the company of the active service of its best qualified members. The officers acquire an experience and a practical insight into the business which should be made to count in the directors' meetings. Especially is this true of the secretary and the president. The duties of the treasurer, however, as ordinarily prescribed, bring him but little into touch with the actual insurance business, and this office may well be held by any responsible person, regardless of other connection with the company. An official or responsible employee of a local bank often makes a desirable treasurer, since he usually has the requisite training and the conveniences for keeping accurate accounts with a minimum of labor and expense. Moreover, his methods of keeping accounts may give the secretary valuable suggestions in regard to the keeping of his books, for, with

all his knowledge of farm risks and mutual insurance principles, the secretary is seldom a skilled bookkeeper or accountant. In exceptional cases it may be found expedient to elect a secretary who at the time has no farm property to insure and therefore can not be a member of the company in a technical sense. He may be a retired farmer, for example, who for years has been an active member of the company.

While the directors as a body are responsible to the members, it involves needless expense to have them meet to pass upon routine business. On the other hand, it is undesirable to leave too much to the judgment of a single individual. The best plan, probably, is to provide for an executive committee to pass upon all matters of importance which are more or less routine in their nature. The president, secretary, and vice president properly constitute such a committee. The first two are connected actively with the details of the business in any case. There seems good reason for making the vice president the third member of this committee, since his duties as a committee member will keep him in touch with all angles of the business and qualify him for the duties of acting president, which he may be called upon to perform. By this plan the regular meetings of the board of directors may be reduced to about four a year. Special meetings of the board should be called whenever any extraordinary problems confront the company.

Another important committee for which all companies should provide is an auditing committee. It is almost impossible to over-emphasize the importance of a thorough annual audit of the books of the company. It is an added incentive to the officers in charge of the books to keep their records accurate and in good form.

While cases of misplaced confidence appear to be rare in companies of this kind, nevertheless provision should be made to prevent the possibility of misconduct or misuse of funds. Even though the reputations of the officers are such that fraud on their part seems impossible, it is desirable to maintain sound business practices and to guard against insinuations by some disaffected member. The officers themselves should insist upon a thorough annual audit as a matter of self-protection. It may be desirable to have the books audited annually by an experienced accountant, but this involves considerable expense. Under ordinary circumstances, especially for the company of moderate size, the most practicable auditing committee consists of members of the company. In a committee of three the chairman and at least one other member should be selected at the annual meeting from outside the board of directors. It may be well to have the third member selected by the board from their own number in order that no needless misunderstandings may arise.

APPLICATIONS FOR INSURANCE.

The most important single problem confronting a newly organized farmers' mutual fire insurance company is that of securing a sufficient number of acceptable applications for insurance within a reasonable distance of the home office. In passing upon applications, the standard applied to risks must vary somewhat with the economic development of the community which the company is intended to serve. In a new or undeveloped community risks will have to be accepted which, in a community more advanced in a material way, can and should be rejected. The cost of insurance will be higher, of course, in the undeveloped community, but since commercial rates for insurance, if protection of this type is available on any terms, will also be much higher, the saving through cooperative enterprise in fire protection may equal or even exceed the saving accomplished in the more advanced community.

While the standards for the material forms of the risk may thus vary to suit the locality, the requirements as to personal character of applicants need not and should not vary. A thriftless or dishonest person has no place in a farmers' mutual insurance company. When an individual is known to have these characteristics, it is the duty of the management not only to avoid soliciting his insurance, but to reject his application if it should be tendered. Those in charge of the company have no right to endanger its stability in order to avoid this unpleasant duty. Where mere suspicion of dishonesty exists and the management does not feel justified in rejecting an application for insurance and membership in the company, special precaution should be taken to see that the property is conservatively valued. Even where no suspicion of dishonesty exists, due care always should be exercised to avoid the creation of needless temptation through overinsurance, which frequently leads to a bad moral hazard.

With the above statements few, if any, of the men experienced in farmers' mutual insurance will disagree. On the question of who should solicit or accept applications, however, a variety of opinions will be found. In about 35 per cent of the farmers' mutuals all applications are taken by one or more special agents, and in an additional 10 per cent of the companies applications are taken at least in part by special agents. The other 55 per cent of the companies restrict the right of taking applications to the directors exclusively, to the officers exclusively, or to the directors and officers.

The extent to which the cooperative spirit has been developed in the community should be taken into consideration in deciding upon a plan for securing business. It is believed, however, that the plan of charging the directors with this duty, wherever it can

be put into practice, will increase the cooperative spirit. It will help to give the organization a broad and firm basis and make it more truly a community affair. Under the agency plan, on the other hand, there is greater danger that the interests of the company will be sacrificed in an effort to secure large applications and commissions.

The compensation for securing business should be a fixed amount rather than a percentage of the advance charges collected. The fixed amount leaves the one who takes the application unbiased as to the valuation and the consequent amount of insurance written. While a thoroughly conscientious and unselfish person may refuse to let the matter of his own compensation influence his judgment, there is no doubt as to the wisdom of eliminating temptation wherever possible.

The application should contain an accurate and fairly detailed description of the property to be insured and should also contain the proposed member's formal acceptance of the articles of incorporation and the by-laws of the company, together with his agreement to meet his share of all losses and legitimate expenses. The latter obligation frequently is embodied in a separate assessable note, though in most cases where this is done it merely adds another paper to be cared for, without corresponding advantage.

The policy or membership fee and the initial premium should be forwarded with the application to the secretary, unless a plan for periodic settlement of accounts between the company and the person receiving the application has been provided. Such application, when fully and regularly approved by the company's representative taking it, should impose full liability upon the company until a policy is issued or the application has been formally rejected. In the absence of such a provision, especially where the secretary does not give his full time to the duties of his office, the delay in issuing a policy may mean that the applicant goes without protection for some time after he has taken all necessary steps on his part to have his property insured.

When a conditional or tentative approval by the company's representative taking the application is provided for in the by-laws, an application so approved should not bind the company until finally passed upon and accepted at the company's home office. In any case, after due consideration of the application, either a policy should be issued and forwarded to the applicant or the application, together with the advance charges collected, should be returned promptly with formal notice that it has been rejected. The reason for rejection should be clearly stated whenever practicable.

INSPECTION OF RISKS.

By means of reasonable care in the selection of the risks from a physical standpoint, together with precautions to eliminate the moral hazard, it is possible for a farmer's mutual fire insurance company to bring the average annual loss ratio considerably below what would be expected from the experience of larger commercial concerns insuring farm risks. Since the expense item in the annual budget of a farmer's mutual is easily held below the corresponding outlays of commercial concerns, a considerable saving to the members can be effected. To stop here, however, is to fall far short of realizing the possibilities of a farmers' mutual insurance company. The annual fire loss in the United States, within as well as outside the farmers' mutuals, is very much higher than it should be, judged by the experiences of other countries. A large percentage of the fires that occur are readily preventable, and there is no better way for the company to live up to its purpose of safeguarding its members against disastrous loss burdens than to eliminate, as far as possible, all preventable losses.

The first and perhaps the most important step in a program for the improvement of risks and the elimination of preventable losses is an efficient system of inspection. Many defects that constitute fire dangers could be discovered and removed by a more thorough inspection than is now generally made by the representatives of the company who take the applications for insurance. It may be doubted, however, whether highly satisfactory results can be secured without the employment of a special inspector who makes a careful study of fire dangers and who inspects thoroughly all risks of the company at least every two or three years. It may be found that annual inspection is necessary for the best results. The experience of other classes of mutuals has amply demonstrated that money spent for efficient inspection of risks is a wise and profitable investment.

FORM AND TERM OF POLICY.

A reasonable uniformity among the farmers' mutuals in regard to their policy forms is undoubtedly desirable and should be encouraged. The advisability, however, of requiring them to use a standard policy applicable to all classes of insurance may be questioned. In many instances where the use of the standard policy by these companies has been prescribed by State law, they have continued to consider the by-laws printed on the back of the policy as the real agreement between the company and the insured.

It is unquestionably a condition essential for success in cooperative effort that the agreement between the organization and its members

be read and understood. The standard insurance policies of the various States, it must be admitted, are difficult reading for one not accustomed to legal phraseology. The provisions contained therein regarding manufacturing establishments and their operation are of no interest to the members of a farmers' mutual. These considerations appear to have induced the legislatures in a majority of the States that have special legal provisions for farmers' mutual companies to exempt such companies from the use of the standard fire insurance policy of the State.

A difference of opinion exists as to the term of years for which a policy should be written. A small number of the farmers' mutuals make their policies perpetual in form. The advantages claimed for such a plan are that it tends to give permanency to the company, and that it saves the expenses incident to the making of renewals. However, as the value of a given farm risk changes from time to time with the addition of new buildings, the deterioration of old ones, increase or decrease in the amount of stock or machinery on hand, such a policy, as a rule, will require changing at intervals, making it in effect a new contract, even though technically the old policy continues in force. There is also the danger that in the absence of a specific termination of a policy, the revaluation of the property will be unduly postponed, resulting in cases of overinsurance, with the consequent tendency toward a bad moral hazard. The duration of the limited-term policies issued by the farmers' mutuals varies from a single year to 10 years. The usual length of term, however, is five years, and more than seven-tenths of the farmers' mutuals write their policies for this period of time.

LIMITING THE SIZE OF INDIVIDUAL RISKS.

It is very important, especially in the early history of a company, when the total amount of its risks is relatively small, to limit carefully the amount of insurance written on a single building or on a group of buildings subject to the same fire. Not to limit the size of the risk is to invite disaster. The exact limit fixed upon such single risks must be determined to some extent by the average value of farm buildings in the community. It is perhaps safe to say, however, that no recently organized company should attempt to write more than \$2,000 on a single risk.

Some provision for sharing the liability involved in the larger risks with one or more other companies should be made whenever possible. Two ways of accomplishing this division are in vogue. One of these is the plan usually referred to as joint or concurrent insurance. Under this plan two or more companies issue separate policies for specified amounts on the same risk, care being taken that

the total amount of the two or more policies shall be well within the actual value of the property.

The second plan of sharing liability with other companies is that of reinsurance. Under this plan the original company in the first place insures the entire risk, but later makes a contract with another insurance company to assume a certain part of the liability.

The first of these two plans is the more easily applied, since the two or more companies sharing a given risk are practically independent of one another; hence uniformity in practice or approval of one another's methods is not required. Under the second plan the knowledge and approval of one another's methods and affairs are necessary before an agreement for reinsurance can be brought about.

EVILS OF BLANKET INSURANCE.

From the point of view of the company the insurance written should be as specific as possible. The practice of writing blanket insurance, that is, of covering a variety of insurable objects by a single lump sum of insurance, is unfair both to the company and to the members with a small amount of property to insure. It enables a member owning a large amount of property to protect himself against loss with a relatively small amount of insurance. In extreme instances all the personal property located on several separate farms has been thus covered by a single sum of insurance. Since loss of more than a small fraction of this property by any one fire is impossible the owner, under such a blanket plan, can protect all his personal property by an amount of insurance equal perhaps to 10 or at most 20 per cent of the value. A corresponding opportunity to secure more protection than is actually paid for is not open to the member who has but few items of personal property and these in a large measure subject to destruction by a single fire.

Inasmuch as under the blanket plan the property covered by the insurance is invariably out of proportion to the amount of insurance written, it makes the assessment per hundred of insurance unduly large, and thus in addition to giving an unfair advantage to the more wealthy members, it discredits the work of the company by making the average cost of protection appear higher than is actually the case. A number of the farmers' mutuals have reduced their rate of assessment materially, while at the same time they have made their assessments more just, by the simple method of changing their plan from one of giving blanket insurance to one of specific enumeration and valuation of the various kinds of property covered by the contract.

LIABILITY OF THE COMPANY AND OF THE INSURED.

Even large legal-reserve companies find it necessary in their contracts to exempt themselves from liability for losses due to such catastrophes as invasion, insurrection, riot, or civil war. A local mutual is, of course, even less capable of assuming liability for loss caused by such disasters, in which the destruction of property may surpass all expectations or estimates for which an insurance company can reasonably make provision. Since the destruction by windstorm of a building in which light and heat are used involves the probability of fire resulting from the fall, it is proper for the company to arrange for exemption from liability in the case of such fire loss. The insured should rely upon windstorm insurance for indemnity against loss primarily due to the windstorm hazard.

A few farmers' mutuals limit their liability for indemnity in case of all losses, whether total or partial, to three-fourths of the value of the property. Where the insurance written is limited to three-fourths of the actual value of each risk, as is here advocated, the member suffering a total loss bears one-fourth of the loss himself. A part of a partial loss can be borne by the insured with even less hardship. Prevailing practice requires full indemnity in the case of partial losses, however, up to the amount of the insurance carried, and this practice has been recognized in the accompanying by-laws.

The main reason for not embodying in the accompanying by-laws the more logical practice of three-fourths indemnity in all cases is the danger that unfair competition might result. In spite of its reasonableness, the practice offers an opportunity for agents of competing companies to alienate members who have suffered partial loss, by pointing out to them the greater indemnity that would have been paid by another company. A recent loser is likely to overlook the lessened cost of insurance resulting from the three-fourths provision, in his contemplation of the greater indemnity that he would have received under the full indemnity plan for partial losses which another company offers. He is not reminded, and may himself forget, that as a total loser he would be required to bear part of his own loss in either company. Hence, until insurance companies in general agree to adopt a better practice, it may be disadvantageous for a local mutual to adopt the three-fourths plan. Where a company already has adopted such a plan, however, and where the members understand and appreciate the closer approach to justice given thereby, it should be continued.

The liability of the insured is either limited or unlimited. Unlimited liability in this case means that a member binds himself to pay his pro rata share of all losses and legitimate expenses of the company. Many persons have objected to this unlimited liability feature

in farmers' mutuals, although about seven-tenths of the companies are doing business successfully under this plan. It is argued that the apparently impossible might yet come to pass, that is, that losses in such number and amount might be experienced by a company that the necessary assessments would bankrupt the members who had not suffered fire losses. The fact is that in a farmers' mutual company with a reasonable number of risks, located on separate farms, anything corresponding to a conflagration loss is inconceivable. The only exception would seem to be a frontier community in which extensive prairie or forest fires were still possible.

REDUCTION AND CANCELLATION OF INSURANCE.

Inasmuch as the value of the insured property of a farmer changes from time to time, it becomes necessary to provide in the contract for readjustment in the amount of insurance. The opportunity for such readjustment should be open to the insured as well as to the company. The contract should provide also for the cancellation of the policy at the option either of the company or of the insured. No attempt should be made on the part of the company to retain a man who no longer desires to be a member, and it is absolutely necessary for the safety of the company to reserve the right arbitrarily to cancel any policy upon giving fair notice. The reasons for the company's wish to cancel may be perfectly valid from a practical standpoint and yet be of such a nature that they can not be argued with the insured. Such is the case in practically every instance where a bad moral hazard is discovered.

When cancellation takes place at the initiative of the insured, it is reasonable to charge him a short-term rate which is higher than the pro rata cost for the whole term of the policy. This is merely a proper recognition of the expense that the company has incurred in placing the insurance upon its books. The balance, if any, of the advance charges paid by the member, after the deduction of such short-term rate, should be returned. The by-laws should provide, however, that in case of voluntary cancellation by the insured following heavy loss experiences, he must be held liable for his share of all losses and legitimate expenses incurred by the company before such cancellation. Unless this is provided for there is the possibility that a member may cancel his policy because unusually heavy losses have been incurred which will make the next assessment higher than the average.

When, on the other hand, cancellation takes place at the initiative of the company, only the pro rata cost of insurance for the time protection has been given should be deducted from any advance charges paid by the insured. If a short-term rate is applied under these conditions the insured is likely to feel that he has been mistreated and wilfully defrauded.

FEES AND ASSESSMENTS.

A reasonable policy fee, or membership fee, should be provided for in the by-laws. This fee is usually large enough at least to compensate the representative of the company who takes the application and makes a survey of the risk.

Apparently many of the farmers' mutuals, in their early history, followed the plan of levying assessments after each material loss, and a few companies still adhere to this plan. It has been found, however, that after a company has reached a fair size this plan proves needlessly burdensome to the officers and also involves unnecessary expense in notifying members of their assessments and in receipting for these assessments when paid. The members themselves frequently find it annoying to be called upon for small assessments several times during the year. Other companies have adopted the plan of borrowing money with which to pay losses as they occur, and levy an assessment sufficient to repay the loans at the close of the business year.

An increasing number of farmers' mutuals, however, are adopting the plan of requiring the prepayment of an initial premium at least equal to one year's average cost and then collecting at the beginning of each succeeding year of the policy term an annual assessment in advance. This plan not only obviates frequent assessments but also eliminates much of the trouble occasionally experienced in enforcing payment by delinquent members. The fact that a reasonable amount of money is always on hand in the treasury of the company further tends to inspire confidence in the organization both on the part of the members and on the part of business men with whom the company or its policy holders may wish to deal.

Where the annual prepayment plan has been adopted the initial premium as well as the successive annual assessments should be based on a liberal estimate of the needs of the company for the coming 12 months, taking into consideration any funds already on hand. Should it be found, however, that the funds have become exhausted some time before the next regular assessment, the management should not hesitate to make good the deficiency by levying a special assessment upon all risks insured at the time of the occurrence of the unusual losses that exhausted the company's funds.

In the case of special assessments, as well as in the case of all regular assessments when levied in arrears, it is important that the payment of all dues be enforced in a businesslike manner. Several companies have suffered loss of reputation, and subsequently of membership, because of their failure to take prompt and effective measures to enforce their assessments. Once it is understood that the management of the company means what it says in its assessment

notice, little trouble is experienced in the collection of its dues, except perhaps from renters who have removed their insured personal property to some other State or locality.

CLASSIFICATION OF RISKS.

With relatively few exceptions the farmers' mutual fire insurance companies of this country hitherto have charged the same rate for all classes of farm property. In explanation of this practice it may be said that little information has been at hand on which a classification of the various kinds of farm property could be based. It also has been argued, for example, that while a barn may involve a greater fire hazard than a dwelling, each member, as a rule, owned and insured one building of each kind; hence little injustice was done by taking the more hazardous barn at the same rate as the less hazardous dwelling. Especially, it has been argued that the classification of property would involve an undesirable amount of additional work for the officers of the company, particularly for the secretary in making out his notices and records of assessments. The amount of insurance on each class of risk would have to be multiplied by its particular rate and then the sum of these products ascertained for each policy, while under the current practice the determination of a member's assessment involves but a single calculation.

In spite of these arguments, all of which must be admitted to have more or less weight, a reasonable classification of risks is required by considerations not only of justice but also of expediency. There is, after all, a very considerable difference in the nature of the property offered for insurance by different farmers. In one case the more hazardous barn may be worth twice as much as the less hazardous dwelling, and in another case a reverse relation between the two may exist. One farmer insures a large number of live stock and another does not. Still further, experience is bringing out more and more clearly that farm buildings put to the same use are by no means equally hazardous. The material of which they are constructed, the location with regard to other buildings, the absence or presence of proper lightning rods, very materially affect the fire hazard. In fact, this differentiation of risks with reference to the fire hazard is increasing rather than decreasing as the community progresses from an economic standpoint. While in the past practically all farm buildings were built of wood with shingle roofs, an increasing number of buildings are now constructed of brick or stone, while slate, tile, or metal roofs are even more frequent. The larger commercial companies, and also the larger mutuals that either classify or carefully select their risks, are making increased efforts to secure as risks farm buildings so constructed that the fire hazard

is reduced to a minimum. Unless the local farmers' mutual is willing to make concessions from its average rate for a risk of this kind, such risk is likely to be lost to the company. Furthermore, by giving reasonable concessions in its charges on desirable risks, the company offers a strong inducement to the farmer to improve his property by eliminating needless fire dangers.

A suggestive classification of farm property will be found in the accompanying by-laws. If an initial premium proportionate to the hazard is charged, and this premium is used as the basis for all assessments on the plan also provided for in the by-laws, the added work imposed upon the secretary by classification will be very small. Such a classification will enable a company to make more equitable charges for insurance, to safeguard itself against competition, and to encourage the improvement of its risks.

The method of handling the classification is further explained by the application and policy forms attached. In the space in the application for summarizing the insurance by classes will be found suggestive rates for each class. These rates, like the classification itself, will need adjustment in many instances in order to reflect, as nearly as may be, both average insurance cost and relative hazards on the different classes.

SETTLEMENT OF LOSSES.

The duty of the insured to prevent and to limit fire losses as far as possible should be clearly expressed in the by-laws. A provision should also be made to the effect that a sworn statement may be required of the insured as to his knowledge and belief in regard to the cause of the fire and the amount of damage or loss. Arbitration should be provided for to settle difficulties that may arise as to the amount of indemnity due. The simplest and perhaps the most satisfactory way of arranging for this arbitration is to have the company and the insured each select one member of the arbitration board, and then require the two so chosen to select a third member.

The cost of the arbitration should be borne equally by the company and the insured. It is sometimes argued that the party who, according to the findings of the board, is proven to have been in the wrong should pay the entire cost of arbitration; or, in other words, that the cost should be borne by the insured unless the award previously offered by the company is increased by the decision of the board. When such a provision exists, however, it frequently causes the arbitration expenses to influence the action of the board in a needless and unwarranted manner. It is felt, for instance, in the case of a member with modest resources who may have been honestly mistaken as to the value of the destroyed property, that circumstances justify the rais-

ing of the previous award of the company by a very small amount in order to throw all expenses of arbitration upon the party which can better afford to bear them. Such action, however, is decidedly unfair to the company. The addition to the award and the expenses of arbitration may not in themselves be serious considerations, but by having its original award set aside the company's reputation for fairness in the settlement of its losses is unjustly undermined.

The damage by fire or lightning to a given piece of property often appears to the owner much more serious than it really is. For this reason a provision to the effect that the company may satisfy the claim against it by repairing or rebuilding frequently proves of value.

RESERVE.

The question of whether a farmers' mutual insurance company should aim to establish and maintain a reasonable reserve fund is closely related to the question of advance or post assessment already discussed. The reserve problem, however, leads still further into the question of how far the farmers' mutuals shall imitate the plan now imposed by law upon all capital-stock insurance companies and, in general, upon larger mutuals; namely, that of maintaining a certain reserve proportionate to the amount of business transacted. It is frequently held that to build up a reserve fund deprives the members of capital which each member might as well have in his own possession until it is needed by the company. The truth of the argument, so far as it goes, must be conceded. However, the necessary additional amount to be contributed by each member in order to build up a reasonable reserve is so small that it can not affect seriously the business operations or the prosperity of the individual members.

A reasonable reserve in the treasury of the company, on the other hand, performs a very useful function by equalizing the assessment from year to year. In case unexpectedly heavy losses should be experienced it may thus prevent dissatisfaction on the part of the members. In an extreme case it may even save the company from dissolution. The opinion appears to be growing among farmers' mutual insurance men that under a plan of annual assessments a reserve of about \$3.000 per million of insurance in force is useful as a shock absorber in the loss experience of the company.

AMENDMENT OF BY-LAWS AND ARTICLES OF INCORPORATION.

The by-laws, as well as the articles of incorporation, should prescribe carefully the method of their own amendment. A reasonable permanency in the company's plans and methods doubtless requires that something more than a mere majority of favorable votes should

be necessary to bring about an amendment. The percentage of favorable votes required should not be so large, however, that a relatively small number of members, aided by mere inertia or the attitude of opposition to all change on the part of other members, can block a desirable reform. A three-fifths majority represents a suitable requirement for amendment to the by-laws. The majority required for change in the articles of association logically should be slightly higher. Even here, however, two-thirds rather than three-fourths is believed to constitute a reasonable majority.

No amendment should be passed without due warning to the members that a change is contemplated. Such warning may be provided for by requiring that a notice of a proposed amendment shall be sent to every member a reasonable time before the meeting at which the amendment is to be considered. This special notice may properly be omitted only when an amendment has been formally acted upon and recommended by a majority vote at a regular or regularly called meeting of the members preceding that at which final action is contemplated.

SUGGESTIVE ORGANIZATION AND BUSINESS FORMS.

The accompanying suggestive articles of incorporation, by-laws, application, and policy embody the principles emphasized in the preceding pages. In many States it will be necessary to modify them to conform to local conditions and to comply with legal requirements. The advice of the State insurance commissioner should be freely sought in all cases of serious doubt. Especially is such consultation necessary when the question concerns the laws, or the interpretation of the laws, regulating insurance in the State. Even when changes are necessary, however, it is believed that the accompanying suggestive organization and business forms will be found useful.¹

¹ So far as its facilities permit, the Office of Markets and Rural Organization of the United States Department of Agriculture is ready to assist individual rural communities both in the formation of new organizations and in the improvement of existing insurance companies.

ARTICLES OF INCORPORATION.

——— FARMERS' MUTUAL FIRE INSURANCE COMPANY.

We, the undersigned, residents of ——— County, State of ———, who severally own property within said ——— County, having a total insurable value of ——— dollars, which we desire to insure, said property consisting of ——— separate risks, hereby associate ourselves together as a body corporate, and for that purpose subscribe to and adopt the following articles of incorporation:

ARTICLE I. The name of the corporation shall be ——— Farmers' Mutual Fire Insurance Company.

ART. II. The principal office of this company shall be located in ———.

ART. III. The business of this company shall be to safeguard its members, so far as possible, against property losses by reason of fire or lightning, and to distribute among all the members, on the mutual-insurance plan, any loss by fire or lightning which may occur in spite of all reasonable precautions.

ART. IV. The business territory of this company shall be confined to ———.

ART. V. Membership in this company shall be limited to persons who own or have a substantial interest in farm or country risks or similar detached risks within the limits of cities and villages which may be insurable under the rules of the company, in compliance with the laws of the State of ———.

ART. VI. The management of this company shall be vested in a board of nine (9) directors, who shall be elected for such term and in such manner as the by-laws shall provide.

ART. VII. These articles of incorporation may be amended by a two-thirds vote of the members present at any annual meeting or any regularly called special meeting (a quorum being present), at least thirty (30) days' notice of such proposed amendment having been given.

ART. VIII. The duration of this corporation shall be ——— years.

ART. IX. Until the first regular meeting of the members, the following shall act as a board of directors:

(Name.)

(Address.)

1.

2.

3.

Etc.

Signed (by incorporators):

(Name.)

(Address.)

1.

2.

3.

Etc.

BY-LAWS.

FARMERS' MUTUAL FIRE INSURANCE COMPANY.

SECTION 1. Purpose.

The purpose or object of this company shall be to protect its members against property losses from fire or from lightning. In the accomplishment of this purpose the company shall employ the following means:

First, careful periodic inspection of the property insured, followed by advice and warnings against fire dangers, and, when necessary, by orders for the improvement of bad risks; also, so far as possible, the general enlightenment of its members on matters of safe construction and proper maintenance and care of property in order to avoid danger of loss or damage.

Second, the distribution among its members on the mutual-insurance plan of any loss caused by fire or lightning which may occur in spite of all reasonable precautions.

SEC. 2. Property that may be insured.

This company shall insure only farm or country property consisting of detached dwellings and their contents; farm buildings, including silos, and their contents; farm machinery; vehicles; grain and hay in bin, stack, or loft; and live stock; and detached risks of similar hazard within the corporate limits of cities or villages, not less than 100 feet distant from all other risks in places lacking adequate fire protection, and not less than 50 feet distant in places having efficient fire protection: *Provided*, That no property of any class not considered reasonably safe by the board of directors or their representatives shall be insured: *And provided further*, That old and dilapidated structures, buildings wherein fire is used and the flues are defective or dangerous, paintings, jewelry, money, or securities or other evidences of ownership or of credit, shall in no case be insured by this company.

SEC. 3. Membership and meetings.

(a) MEMBERSHIP.—The membership of this company shall comprise all persons who have property insured therein.

(b) ANNUAL MEETING.—The annual meeting of the company shall be held on the third Tuesday in January of each year, in the city of ———. The exact place and hour of meeting shall be designated by the executive committee hereinafter provided for. Notice of such meeting shall be sent by the secretary to each member at least 15 days before the date of the meeting.

(c) SPECIAL MEETINGS.—Special meetings of the company shall be called whenever the board of directors by a two-thirds vote shall so order, or whenever one-fourth of the members shall petition for such meeting.

(d) VOTING PRIVILEGE.—Each member shall be entitled to one vote on all questions arising at the annual or special meetings of the company. No vote by proxy shall be allowed.

(e) QUORUM.—At all annual or special meetings of the company 15 members shall constitute a quorum.

SEC. 4. Directors.

(a) ELECTION AND TERM.—At the first annual meeting of the company nine directors shall be elected to succeed those designated as a temporary board in the articles of incorporation. The directors so chosen shall be divided by lot into three classes of three directors each. Those in class 1 shall hold office for one year; those in class 2 for two years; and those in class 3 for three years. At all subsequent annual meetings three directors shall be elected, to hold office for a term of three years, or until their successors are elected.

(b) METHOD OF FILLING VACANCIES.—Vacancies in the board of directors may be filled temporarily by the remaining members of the board. Persons so chosen shall hold office until the next annual meeting, when such vacancies shall be filled by election for the unexpired term.

(c) POWERS AND DUTIES.—The board of directors shall have charge of all the business of the company. They shall hold meetings at such times and places as they deem necessary. They shall elect the officers of the company. They shall direct the levying of all assessments and shall appoint, or authorize the appointment of, all inspectors, adjusters, and other employees of the company. They may divide the business territory of the company into districts and apportion among themselves the agency and supervision of these districts in such manner as will best serve the interests of the company. They shall designate depositories for the company's funds.

(d) QUORUM AT BOARD MEETING.—Five directors shall constitute a quorum at a board meeting.

SEC. 5. Officers.

(a) TITLES, ELECTION, AND TERM.—The officers of this association shall consist of a president, a vice president, a secretary, and a treasurer, and shall be elected by the board of directors from their own number: *Provided*, That the office of treasurer may, by a two-thirds vote of the board, be filled by any competent and trustworthy person without reference to other connection with the company. If the treasurer is not a director, he shall attend and be heard at the meetings of the board, but shall have no vote at such meetings. Each officer, unless removed by a two-thirds vote of the board, shall hold office for one year or until his successor has been elected and qualified.

(b) DUTIES OF THE PRESIDENT.—The president shall preside over all meetings of the board of directors. He shall also call to order all meetings of the company and shall preside until a temporary chairman has been elected. He shall sign all policies, vouchers, or orders issued by the company, and shall perform such other duties as are usually performed by such officer, or as the board may assign to him. It shall also be his duty to see that the auditing committee hereinafter provided for does its work, and to fill by appointment any vacancies in this committee that may occur.

(c) DUTIES OF THE VICE PRESIDENT.—The vice president, in addition to his duties as a member of the executive committee hereinafter provided for, shall perform all the duties of the president during the absence or inability of that officer.

(d) DUTIES OF THE SECRETARY.—The secretary shall keep a complete and accurate record of all transactions of the company. He shall write and sign all policies, vouchers, or orders issued by the company. He shall, under the direction of the board of directors, have charge of the levying of all assessments and the collection of these assessments and any other money due the company, and shall turn over all money so collected to the treasurer. He shall make a complete and accurate report of the year's business at each

annual meeting of the company, and shall perform such other duties as the board may assign to him.

(e) **DUTIES OF THE TREASURER.**—The treasurer shall, under the direction of the board of directors, have charge of all the funds of the company. He shall deposit said funds in the depository or depositories designated by the board. He shall pay all vouchers or orders properly attested by the secretary and the president and shall make a complete and accurate report of the finances of the company at each annual meeting.

(f) **BONDS.**—The secretary and the treasurer, before entering upon their respective duties, shall each give bond in such sum and in such form as shall be required by the board.

SEC. 6. Committees.

(a) **EXECUTIVE COMMITTEE.**—The president, secretary, and vice president shall constitute an executive committee, which shall exercise such powers and perform such duties as may be delegated or imposed by the board of directors, or as in these by-laws provided.

(b) **AUDITING COMMITTEE.**—The members shall at each annual meeting elect two competent persons, who, together with a third person selected by the board from their own number not later than December 31 of the current year, shall constitute an auditing committee. Said committee shall audit carefully all books and accounts for that year and report their findings at the next annual meeting. A special audit of such books and accounts by an expert accountant may be ordered by the members at any annual meeting or any regularly called special meeting. Such special audit may also be ordered at any time by the board of directors.

SEC. 7. Salaries.

(a) **SALARIES OF DIRECTORS.**—Each director shall receive \$2 per day and necessary expenses for such time as he actually spends in transacting the business of the company. The compensation for taking applications for insurance shall be equal to the policy fee provided for in section 12, and no per diem shall be allowed directors for such services.

(b) **SALARIES OF OFFICERS AND EMPLOYEES.**—The officers and employees of the company shall receive such reasonable compensation as the board of directors shall determine: *Provided*, That no officer who is also a director shall receive pay both as a director and as an officer for the same service.

SEC. 8. Applications for insurance.

(a) **RECEIVING APPLICATIONS.**—It shall be the duty of the directors, each in his own community, or in such district as the board shall designate, to receive and at their discretion to solicit applications for insurance from all persons of good character and reputation who are the owners of property insurable under the rules and regulations of this company. All such applications must be approved and signed by the director before being forwarded to the secretary and, unless otherwise ordered by the board, must be accompanied by the policy fee and initial premium hereinafter provided for. Before indicating his approval of an application the director shall satisfy himself by means of careful personal inspection and survey that the description of the property is correct and that the risk is in all respects a desirable one; or if serious defects are found he shall see that these are remedied before his approval is given. In case of less dangerous defects that can not be readily remedied, or that the owner is unwilling to go to the expense of removing, the director shall, if it seem to him proper, give the application his conditional approval, accompanying the application with a full and accurate statement of his reasons for such conditional approval.

(b) **FINAL APPROVAL BY THE COMPANY.**—An application reaching the secretary with the conditional approval of a director shall be passed upon by the executive committee before a policy is issued to the maker of such application. An application received with the full approval of a director may, unless the board otherwise orders, be passed upon by the secretary, who, in case no errors or inconsistencies or other reasons for delay or for reference to the executive committee are discovered by him, shall promptly issue a policy on the basis of said application and forward such policy to the applicant.

SEC. 9. Special inspection of property.

At least once every three years the property insured shall be thoroughly inspected by a competent person employed by the company as special inspector. Said inspector shall carefully examine the flues of all dwellings or other buildings wherein fire is used, note the placing and the condition of stoves and fireplaces and the disposition of ashes therefrom, inquire into the system or method of lighting buildings, examine all lightning rods, and ascertain if fences are properly grounded. He shall take careful notice of any and all defects or dangerous practices. He shall also note the presence or absence of means of combating a fire, such as readily available water supply, or chemical extinguishers, and suitable ladders by means of which the top of the roof can be quickly reached. He shall advise with the insured concerning the general improvement of the risks, and shall recommend specific measures for the removal of conditions materially increasing the hazard thereof. He shall report to the company, upon blanks furnished him for that purpose, the condition of each member's risk or risks, together with the recommendations, if any, made by him for the removal of dangerous conditions. Refusal or neglect on the part of the insured to carry out specific recommendations of the inspector may, in the discretion of the board of directors or their representatives, be made cause for the cancellation of his policy or policies.

SEC. 10. General conditions of insurance.

(a) **TERM OF POLICY.**—Except as hereinafter provided, all policies shall be written for a term of five years, and shall date from the date specified in the application. An application which has the full approval of a director shall cause the insurance applied for to be in full force and effect from the date specified therein, unless and until such application is rejected by the executive committee and notice thereof given to the applicant. An application with the conditional approval of a director shall impose no liability upon the company until approved by the executive committee.

(b) **LIMITS TO THE AMOUNT OF INSURANCE.**—The directors of this company shall exercise due care to prevent the insurance of any property for more than three-fourths or less than one-half of the cash value of the property: *Provided*, That until the company has \$500,000 of insurance in force no single risk or group of property subject to one and the same fire shall be insured for an amount greater than \$1,500, nor shall such maximum single risk exceed \$2,000 until the company has \$1,000,000 of insurance in force, nor shall it later exceed two-tenths of 1 per cent of the insurance in force: *And provided further*, That the insurance placed on live stock shall not exceed an amount per head of \$200 on horses, \$60 on cattle, \$15 on hogs, and \$10 on sheep.

(c) **LIABILITY OF THE COMPANY.**—This company shall in no case be liable for loss or damage from other cause than that of fire or lightning, nor for more than the actual cash value of the property at the time of the loss, nor shall it be liable for loss caused directly or indirectly by invasion, insurrection, riot, or civil war, or by order of any civil authority. If a building or any part thereof fall, except as the result of fire or lightning, the insurance

by this company on such building, or on its contents, shall immediately cease.

(d) **LIABILITY OF THE INSURED.**—The liability of the insured shall be limited to his pro rata share of the losses and expenses of the company, plus a reasonable contribution to the reserve.

(e) **JOINT OR CONCURRENT INSURANCE.**—Property insured in this company shall not be insured in other companies except with the written consent of this company. Where joint insurance is permitted, this company shall be liable only for such part of the loss as the insurance carried in it represents of the total insurance carried on the property, whether the insurance carried in the other company or companies is valid or not.

(f) **INSURANCE TO BE SPECIFIC.**—Buildings shall be separately described, and the value of each building and the amount of insurance thereon shall be stated in the application and in the policy. The value of each class of other property and the amount of insurance thereon shall be similarly stated.

(g) **FALSE STATEMENT BY APPLICANT.**—A false description of the property by the applicant or any false statement by him, either in regard to ownership or relative to any other material fact, shall render the insurance on the property in question void.

(h) **SALE OF PROPERTY AND TRANSFER OF POLICY.**—The sale of insured property shall immediately suspend the insurance thereon, and unless application for transfer of the policy is received and accepted within 10 days after the date of sale, the policy shall be canceled. A policy may be transferred or assigned by obtaining the consent of the company and paying a fee of 50 cents.

(i) **REMOVAL OF PROPERTY AND CHANGES IN FORM OR USE.**—The permanent removal of personal property, or any change or alteration in the form, occupancy, or use of a building affecting it as a risk by increasing the fire hazard, shall render the insurance thereon void, unless the consent of the company has been previously obtained for such removal or change.

SEC. 11. Reduction and cancellation of insurance.

(a) **ACTION BY THE INSURED.**—A member may at any time, upon written request to the secretary and the payment of all valid claims against him, have his policy canceled. He may also, upon showing cause, have the amount of his policy reduced.

(b) **ACTION BY THE COMPANY.**—The company may, upon five days' notice, for refusal to remedy dangerous conditions, or for any other cause deemed sufficient by the board of directors or their representatives, cancel any policy or any part thereof.

(c) **RETURN OF UNEARNED PREMIUM OR ASSESSMENTS.**—When cancellation takes place at the request of the insured the company shall return such part of the premium or last regular assessment as remains after the deduction of one-eighth thereof for each month or major fraction of a month that has elapsed on the current policy year: *Provided*, That should the pro rata cost of insurance for such period exceed the short-term rate above prescribed, the actual pro rata cost shall be deducted. When cancellation takes place at the initiative of the company, such part of the premium or regular assessment shall be returned as is proportional to the unexpired part of the current policy year.

SEC. 12. Fees and assessments.

(a) **POLICY FEE AND INITIAL PREMIUM.**—A policy fee of \$1.50 and an initial premium to be fixed by the board shall be paid by the applicant, or satisfactory security for their payment shall be given by him, at the time of making application for insurance. For additional insurance a member shall be charged,

in addition to the initial premium, a policy fee of 75 cents when the additional insurance applied for is \$500 or less, and \$1.50 when the sum applied for is greater than \$500.

(b) **REGULAR ASSESSMENT.**—Not later than October 20 of each year the board of directors shall determine the rate of assessment for that year, basing such rate upon past experience as to the needs of the company. Said assessment shall be due on or before November 30 of the same year. Policies written on or after December 1 of the previous year and before June 1 of the current year shall be subject to the regular assessment of the current year and to three succeeding regular annual assessments. Policies written on or after June 1 of the current year and before December 1 of the current year shall be exempt from the regular annual assessment of that year, but shall be subject to four succeeding regular annual assessments.

(c) **SPECIAL ASSESSMENTS.**—Should unexpectedly heavy losses occur which can not be met by the funds on hand, supplemented at the discretion of the board of directors by a sum not exceeding two-tenths of 1 per cent ($\frac{2}{10}\%$) of the insurance in force, which may be borrowed, a special assessment shall be levied on all policies in force at the time of such loss or losses.

(d) **NOTICE OF ASSESSMENT.**—Not later than November 1 of each year the secretary shall, by letter directed to the post-office address given in the application, or to the latest address, if he has been informed of a change, notify the member of the amount due from him. He shall also include with this notice such information bearing upon the business of the company as may be considered of practical interest and value to the member. Should the member continue to neglect or refuse to pay such assessment for 10 days after the assessment has become due, the secretary shall send by registered mail a second notice, adding 25 cents to the assessment to cover the extra work and expense occasioned by the member's neglect.

SEC. 13. Suspension, forfeiture of membership, and reinstatement.

(a) **SUSPENSION OF POLICY.**¹—The sending of the two notices described in paragraph (d) of section 12 shall constitute legal notice, and unless payment is received within 10 days after the sending of the second notice the policy in question shall stand suspended until the assessment is paid. The company shall not be liable for any loss suffered by the holder of such policy during the period of suspension, nor shall the later acceptance of the full assessment render the company liable for such loss. The part of the assessment corresponding to the cost of insurance for the period during which the policy was suspended shall be considered a penalty for delinquency.

(b) **FORFEITURE OF MEMBERSHIP.**—One month after the second notice, a policy still remaining suspended shall be canceled, and the holder shall be dropped from membership in the company. Such cancellation shall in no way release the former member from any debt already incurred to the company.

(c) **REINSTATEMENT.**—A person having forfeited his membership under the provisions of paragraphs (a) and (b) of this section may, at the discretion of the board of directors, upon proper application for reinstatement, the payment of past dues, if any, the acceptance of a new policy, and the payment of the regular policy fee and initial premium, have his membership restored.

SEC. 14. Classification and rates.

(a) **CLASSIFICATION.**—Property insured by this company shall be classified as follows, the contents of buildings taking the same classification as the

¹ Where the State law specifically provides the manner in which the insurance liability may be terminated and no suspension of a policy is provided for, direct cancellation without previous suspension may be necessary.

building in which they are kept: *Provided*, That the board of directors shall have power to prescribe rules under which kinds of property not specifically hereinafter enumerated may be placed in one or the other of the following classes, or in additional classes created by the board.

Class A.—Brick or stone dwellings with roof of slate, metal, or other non-combustible material, when properly rodded against lightning.

Class B.—Brick or stone dwellings with wooden roof, when properly rodded. Wooden dwellings with roof of noncombustible material, when properly rodded.

Unrodded brick or stone dwellings with roof of noncombustible material.

Class C.—Wooden dwellings with wooden roofs, when properly rodded.

Unrodded brick or stone dwellings with wooden roof.

Unrodded wooden dwellings with roof of noncombustible material.

Granaries, corn cribs, and hog houses located not less than 100 feet from the dwelling, nor less than 50 feet from the barn, such buildings being properly rodded in all cases where the insurance applied for is \$200 or more.

Live stock not pastured during the summer months except where all fences are properly grounded.

Class D.—Barns properly rodded.

Unrodded wooden dwellings with wooden roofs.

Granaries, corn cribs, and hog houses located nearer the dwelling or the barn than as specified for Class C, or lacking the lightning protection required for that class.

Live stock pastured during the summer months where fences are not properly grounded.

Class E.—Unrodded barns and other property deemed to be of similar hazard.

(b) INITIAL PREMIUM RATES¹ AND BASIS OF ASSESSMENT.—The rates of initial premium for the various classes of property shall be determined by the board of directors, and shall be so adjusted as normally to cover one year's cost of insurance together with a reasonable contribution to the reserve. Assessments shall also be determined by the board, shall be based on the initial premium, and shall constitute a fixed percentage thereof, being equal to, greater, or less than 100 per cent, as the needs of the company may require.

SEC. 15. Losses.

(a) PREVENTION OF LOSS.—It shall be the duty of the insured to cooperate with the company in making his property as safe from loss as may be reasonably possible. In case of fire he shall use his best endeavors to save his property and to protect from further damage such parts thereof as are not destroyed.

(b) NOTICE OF LOSS.—A member incurring a loss shall immediately notify the company, and the latter shall promptly provide for the adjustment of such loss.

(c) STATEMENT OF LOSS.—It shall be the duty of the insured, when so required by the company, to make a complete and sworn statement of the loss incurred by him. Such statement shall include a complete list of the property lost or damaged and the value thereof before the loss occurred, and shall indicate the time of the loss, the member's knowledge or belief as to the cause of the loss, and if by fire, his knowledge or belief as to how such fire originated.

(d) SETTLEMENT OF DISPUTED CLAIMS.—In case of disagreement between the adjuster or adjusters and the member sustaining the loss, the company and the insured shall each select one person, not an officer or director of the company nor a relative of the insured, and the two so chosen shall select a third. These three shall constitute a board of arbitration, and their award shall be

¹ Suggested rates for the classes of property above outlined may be found in the application form (p. 30) under "Summary."

final and binding upon both parties.¹ The members of the board of arbitration shall be compensated on the same basis as is provided for directors, and the costs of this board shall be borne equally by the company and the insured.

(e) **COMPANY MAY REPLACE OR REBUILD.**—The company reserves the right to repair, rebuild, or replace any building or other property damaged or destroyed: *Provided*, That such repaired, rebuilt, or replaced property shall be of a value equal to that of the insured property immediately before the loss occurred.

(f) **PAYMENT OF LOSSES.**—Losses shall be paid within 60 days after the date of adjustment.

SEC. 16. Reserve.

It shall be a part of the working plan of this company to build up and to have on hand a reserve fund of three-tenths of 1 per cent ($3/10\%$) of the insurance in force.

SEC. 17. Amendments.

The by-laws of this company may be amended by a three-fifths vote of the members present at any annual meeting or any regularly called special meeting (a quorum being present), provided notice of the intended amendment has been given in writing to the secretary in time to be included with the notice of such meeting, or provided the submission of such amendment was proposed and approved by a majority vote at the previous annual meeting. It is specifically provided and agreed that any amendment so passed shall immediately upon its passage affect and become a part of all outstanding policies, as well as of those issued after such amendment is made.

¹ The provision in regard to the force of the action of the arbitration board, though in general use by existing companies, may in some States have to be omitted because of conflict with State laws.

Form for outside of application:

Number _____.	
APPLICATION	
for	
Insurance in the	
_____ FARMERS' MUTUAL	
FIRE INSURANCE COMPANY	
of _____	
made by	
----- Name of applicant.	
----- Address.	
Amount of insurance	\$-----
Policy fee	\$-----
Initial premium	-----
Total	-----
Agent's approval:	
This application has my-----approval.	
Full or conditional.	
Signed -----,	
Title -----	
NOTE.—If your approval is <i>conditional</i> , be sure to give your reasons in a letter to accompany the application.	

Officially accepted	filed
rejected	returned
and ordered this----	
day of -----, 191---	
-----, Secretary.	

Form for diagram of farmstead, to go on application:

DIAGRAM OF THE FARMSTEAD.

Assuming the dwelling to be located at the point so labeled, indicate the location of the other buildings on the place in a similar manner, giving the distance from the dwelling and from each other. Buildings not insured, if any, should be indicated by means of a cross over the square, thus: ☒

N.

W.

□
Dwelling.

E.

S.

Form for outside of policy:

No. —.

POLICY

Issued by the

———— FARMERS' MUTUAL

FIRE INSURANCE COMPANY

of —————

To —————,

of —————

—————

Amount of insurance, \$ ————

Policy fee, \$ ————

Initial premium, ————

Total, ————

Expires —————, 192—

Application taken by

—————

Title —————

Form for policy:

FARMERS' MUTUAL FIRE INSURANCE COMPANY

LOCATED AT _____

In consideration of the agreement contained in the application and of dollars (\$.....), duly received, does insure of, subject to the provisions of its by-laws, for a term of years, from the day of, 191.., at noon, to the day of, 192.., at noon, against all direct loss or damage by fire or lightning, except as in said by-laws provided, to the hereinafter-described property, located on the $\frac{1}{4}$ of the $\frac{1}{4}$ of section of township, county, State of

	Value.	Insurance.	Class.
Dwelling, described and indicated in application.....			
Household goods in dwelling.....			
Wearing apparel in dwelling.....			
Provisions in dwelling.....			
Musical instruments in dwelling, as follows:			
Summer kitchen, described and indicated in application.....			
Woodhouse, described and indicated in application.....			
Granary, described and indicated in application.....			
Contents of above-mentioned granary.....			
Corncrib, described and indicated in application.....			
Contents of above-mentioned corncrib.....			
Hog house, described and indicated in application.....			
Machine shed.....			
Farm implements and tools.....			
Wagons, carriages, and harness.....			
Horses and mules, number.....			
Cattle, number.....			
Barn, described and indicated in application.....			
Hay and grain in above-mentioned barn.....			
Silo with contents, described and indicated in application.....			
.....			
.....			
.....			

SUMMARY.

Insurance by class.	Class and rate.	Initial premium.
.....	A .15	.....
.....	B .20	.....
.....	C .25	.....
.....	D .33	.....
.....	E .40	.....
.....	Totals..	.....

And said company promises and agrees to indemnify the insured against loss or damage from the above mentioned causes, in the amounts above specified, not exceeding a total sum of \$, nor in any case exceeding the cash value of the property immediately before the loss or damage occurred.

In witness whereof the _____ Farmers' Mutual Fire Insurance Company has executed and attested this policy on this day of, 191...

..... President.

..... Secretary.

Form for assignment, to go on policy :

NOTICE.—No assignment of this policy shall be valid until approved by the company.

ASSIGNMENT.

For value received, I hereby transfer, assign, and set over unto ----- and ----- assigns all my rights, title, and interest in this Policy of Insurance, and all benefit and advantage to be derived therefrom.

Witness my hand this ____ day of -----, 191__.

Approved at ----- this ____ day of -----, 191__.

-----, *Secretary.*

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BULLETIN No. 531

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

May 28, 1917

RHIZOPUS ROT OF STRAWBERRIES IN TRANSIT.

By NEIL E. STEVENS, *Pathologist*, and R. B. WILCOX, *Scientific Assistant*,
Fruit-Disease Investigations.

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INTRODUCTION.

The increased production of strawberries in the Southern States has resulted in large shipments to northern markets. These shipments have been attended by great losses, due to the decay of the fruit in transit and on the market. In the hope of obtaining information which will assist in reducing this large annual loss, Dr. C. L. Shear and the writers began, in 1915, a study of the organisms and conditions causing decay of strawberries after picking.

This study has included field observations in the principal strawberry-growing regions of Florida, Louisiana, North Carolina, Virginia, Maryland, and Delaware; observations in the markets of Boston, New York, Philadelphia, and Chicago; laboratory studies of the organisms causing strawberry rot; and experimental shipments from points in Florida and Louisiana.¹ These shipments were

¹ Through the cooperation of Mr. George M. Darrow, of the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry, the writers have received strawberries from points in Alabama, Louisiana, Texas, and other States at times when it was impossible for them to visit these regions. The writers are also indebted to numerous fruit growers and shippers, especially in the central Florida region, for assistance.

NOTE.—This paper is of interest to botanists, pathologists, and strawberry growers and shippers, especially in the Southern States.

made to determine the organisms responsible for the decay of strawberries in transit, the chief sources of infection, how infection could be reduced, and to what extent the growth of organisms could be retarded after they had entered the fruit. With this end in view, the shipments were so handled that every berry could be treated in a definite way and the results recorded after an examination of each berry. This necessitated comparatively small shipments. The writers are of the opinion, however, that the accurate data from these small shipments were more significant in determining the points mentioned than shipments in carload lots with the less accurate methods that must necessarily have been used.

CAUSES OF DECAY IN TRANSIT.

CONDITIONS OF TRANSPORTATION.

Long delay, rough handling, and insufficient refrigeration during transit make it impossible for even the best berries to reach the market in good condition.

Shipments from the extreme south to northern markets sometimes take a week or longer. Even firm, sound fruit, well packed, deteriorates in value during this period. A delay of a few hours in the delivery of the berries at their destination may also cause the change from profit to loss on a shipment.

Strawberries usually are bruised unless they are picked too green to be of value for table use. Small containers, such as open crates or pony refrigerators, frequently are subjected to rough handling at points of loading or transfer. When refrigerated cars are used it is necessary to fasten all crates securely in place in order to prevent their shifting during sudden movements of the cars. Bruises to the berries injure their appearance and permit the entrance of decay-producing organisms.

The importance of refrigeration in preserving strawberries during transit has been known for many years. According to Taylor (15, p. 575),¹ it was demonstrated as early as 1868 that strawberries could be shipped from Cobden, Ill., to Buffalo, N. Y., in refrigerator cars maintained at a temperature of 34° to 40° F. The injurious effect of temperatures above 50° F. is clearly shown in the present work (see pp. 7 and 19) and by the experience of shippers in all parts of the country.

CONDITION OF FRUIT.

Strawberries may be in such a condition when shipped that they can not reach the market without great loss, even though rot-producing organisms are not abundantly present. If berries remain in the

¹ Reference is made by number to "Literature cited," p. 21-22.

field until fully ripe, for example, they can not be handled without serious bruising and are soon crushed in shipment.

Varieties differ greatly as to firmness of berry; some can become fully colored before picking and still remain firm for a relatively long time, while others begin to soften before they are colored sufficiently for market. Still others are so delicate when mature that they are bruised by even the most careful commercial handling and are useful only for local markets. Firmness often determines the choice of varieties for commercial production.

The fruit of a variety which ordinarily is a good shipper may under unfavorable conditions lose its firmness. An excess of nitrogenous plant food in the soil is generally believed to induce the growth of soft, succulent berries. Excessive rainfall during the growing and fruiting season has a tendency to produce this effect, especially if accompanied by high temperature. This was noticeable during the shipping season of 1915, especially during May and June, in New Jersey and Delaware, when, within a few hours after berries were picked and before they were placed in cars for shipment, juice would frequently be running from the crates. The fall, winter, and spring of 1915-16, on the other hand, were unusually dry, especially in the extreme south, and it was remarked by growers, shippers, and retail merchants that berries shipped from Florida to northern markets in 1916 reached their destination in better condition than in any previous year.

Severe losses sometimes result from hot weather prevailing during transit or while the fruit is being picked and loaded for shipment. Since this damage is due to the more rapid growth of fungi at the higher temperature it will be discussed later (p. 7).

The shipping qualities of berries may be injured seriously by heavy storms. On February 24, 1916, a rather severe hailstorm occurred at Lakeland, Fla., and for several days its effect on the berries was noticeable; bruises developed into soft spots as the fruit ripened, though the epidermis often was not broken by the hail. In some fields nearly all the berries were bruised, and it was impracticable to prevent the packing of some injured fruit. On March 22, 1916, a very strong wind blew for several hours over all sections of Florida from which strawberries were being shipped. Sand and fine dust were driven by the wind with such force that for several days strawberry plants were coated with dust and the fruit had a dull, dirty appearance. Berries picked during the days immediately following this storm were extremely soft and did not ship well. Severe rainstorms also caused much damage to berries, both by mechanical bruising and by covering them with dirt, which often is difficult to remove.

These and other unfavorable field conditions may result in the production of berries which even with careful handling and thorough

refrigeration can not be transported to distant markets without loss. Although berries may be in the best of condition when picked, they often decay before reaching the consumer, owing largely to the activity of rot-producing organisms.

FUNGI.

Bacterial rots are rare in strawberries. This may be due to the high acid content of the fruit. On the other hand, ripe strawberries, especially if injured, furnish a favorable substratum for the growth of many fungi. Among the less important fungi found were species of *Alternaria*, *Botrytis*, *Cladosporium*, *Dematium*, *Fusarium*, *Mucor*, *Patellina*, and *Penicillium*. All these fungi will grow on strawberry tissue, and under unusually favorable conditions some of them may cause appreciable damage.

Botrytis, long known to occur commonly on strawberries and frequently found in fruit from some sections, is not of first importance as a cause of decay in transit. Berries affected by *Botrytis* in the field are recognized readily and should be thrown out as culls. The growth of *Botrytis* in the ripe strawberry is so slow that but little damage occurs in the short time between picking and marketing.

Penicillium, which occurs frequently in small quantity, has been abundant in only one case which has come under the observation of the writers. In a shipment from Florida in the spring of 1916 in which the berries were very soft, owing apparently to the effect of the severe sand storm previously mentioned, *Penicillium* was very common. It is uncertain whether this was due to the condition of the berries or to some unusual opportunity for infection.

By far the most important cause of rot of strawberries in transit is a species of *Rhizopus*. Not only is this fungus the most common one on strawberries from every section studied by the writers, but in some instances it is almost the only fungus present. During the spring of 1916 the writers examined more than 14,000 decayed strawberries shipped on various dates from three localities in Florida. Most of these were kept until quite rotten, and more than 90 per cent of them developed only *Rhizopus*.

In addition, several hundred inoculations on strawberries of various varieties have been made, and in no case has *Rhizopus* failed to produce typical rot when introduced into a wound (fig. 1). No similar results could be obtained with any of the other fungi found.

RHIZOPUS NIGRICANS.

In his recent monograph of the genus *Rhizopus*, Hanzawa (8) used physiological as well as morphological characters in distinguishing the species. The writers have not investigated the physiology of this fungus sufficiently to compare with Hanzawa's results, but so far as

the morphological characters are concerned the fungus under consideration when grown under certain conditions agrees very well with his description of *Rhizopus nigricans* Ehrb. It is evident from his description that Hanzawa studied the fungus under rather uniform conditions, as the measurements given by no means include its limits of variability.

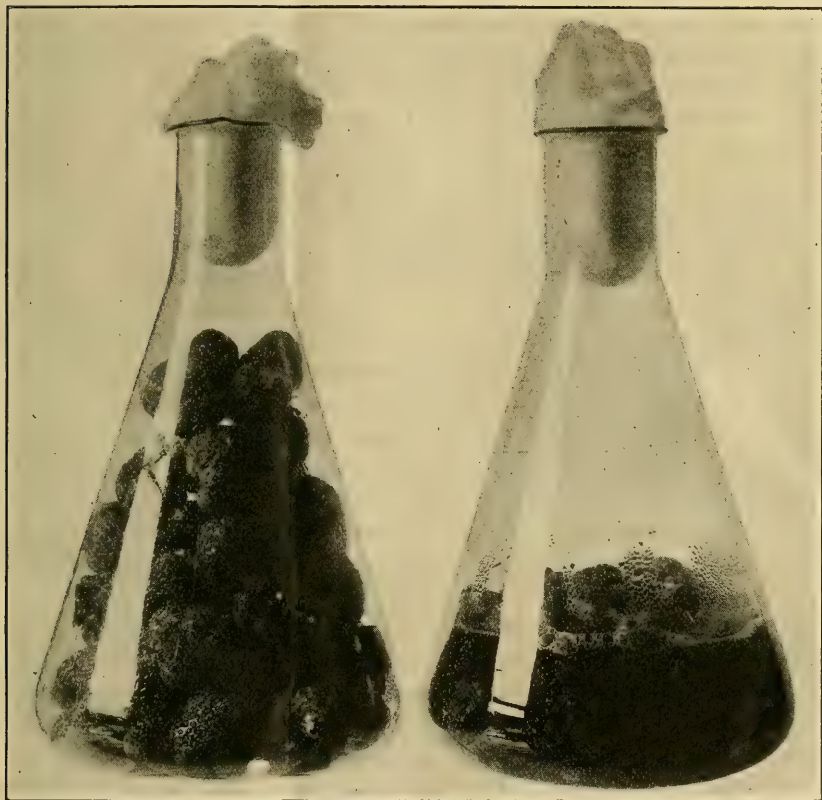


FIG. 1.—Effect of *Rhizopus nigricans* on strawberries of the Missionary variety which had stood for two days at room temperature. Each berry in the flask at the right had been inoculated with *Rhizopus nigricans*.

In connection with studies on the humidity relations of this fungus (p. 7), the writers found that at a temperature of 20° C. the length of the sporangiophore and the size of the columella vary greatly in air of different humidities. For example, in air with a saturation deficit of 17 mm. of mercury, 2.3 per cent relative humidity, sporangiophores are mostly 1 mm. in length, while in saturated air they are from 3 to 4 cm. long. In air with a saturation deficit of 17 mm. of mercury the columellæ are mostly 95 to 100 μ in width; in saturated air they are mostly from 150 to 180 μ wide. The size of spores and

the diameter of hyphæ do not seem to vary greatly with the different humidities. The hyphæ range from 10 to 40 μ in thickness, mostly 20 to 30 μ . The spores are variable in shape and size, being round to oval, or even very irregular, 5 to 15 μ in diameter, the large irregular spores often reaching a length of 27 to 28 μ .

The extreme length of the sporangiophore is apparently developed only in saturated or nearly saturated air. When the fungus fruits on berries in the field or on the tops of boxes exposed to the open air the sporangiophores are short. Near the bottoms of boxes or in closed containers in which the juice leaking from the berries raises the moisture content of the air to near saturation, long sporangiophores are developed. So great is this difference that it might readily be assumed that two species of *Rhizopus* rather than one were concerned. The fact that rhizoids ordinarily are produced below the epidermis of the strawberry in dry air, whereas they are often borne above the surface in moist air, adds to the difference in the appearance of the two forms.

A fact which might readily mislead an investigator as to the true cause of rot in strawberries is the extreme susceptibility of *Rhizopus* to alcohol vapor. During the early part of the writers' investigations it was customary to place decayed berries in moist chambers. The juice leaking from the berries soon raised the humidity to saturation. Yeast developed on this liquid, and alcohol was produced so abundantly that its odor was distinctly noticeable. Under these conditions many rotten berries produced no fruiting bodies of any fungus.

Finally it was observed that if the covers of the moist chambers were removed and the liquid taken up with blotting paper, mature sporangia of *Rhizopus nigricans* would develop on a large number of the rotten berries overnight. This led to an investigation of the effect of alcohol fumes on the fruiting of this fungus.

In this investigation Hempel desiccators containing alcohol of various strengths were used (200 c. c. of alcohol solution per desiccator). It was found that berries inoculated with *Rhizopus* would rot under 95 per cent alcohol without producing any fruiting bodies. The same thing proved true of all strengths of alcohol down to 2 per cent. With 2 per cent alcohol aerial mycelium developed, but no sporangia were produced; with 1½ per cent alcohol apparently normal sporangia on short sporangiophores developed.

In 1896 Goff (6) found that strawberries exposed to alcohol vapor under a bell jar in a refrigerator did not mold, while similar berries kept in the same refrigerator but not exposed to alcohol vapor molded considerably; he makes no mention, however, of the species of fungi present.

PHYSIOLOGY OF RHIZOPUS NIGRICANS.

CHARACTER OF THE ROT PRODUCED.

The rot produced in strawberries by *Rhizopus nigricans* differs from that caused by any other organism the writers have observed and has been briefly described in an earlier paper (13). Its chief characteristic is the rapid collapse of the berry, with the loss of much juice. So great is this loss that the juice often drips from boxes or crates containing strawberries rotted by *Rhizopus*, and this has given rise to the name "leak" applied to this type of rot by shippers and dealers. F. L. Stevens (12) has recognized *Rhizopus* as the cause of this type of rot in strawberries.

HUMIDITY RELATIONS.

In investigating the humidity relations of this fungus in its attack on strawberries, a method already described by one of the writers (14) was employed. Briefly, the method consists in using a series of desiccators filled with mixtures of sulphuric acid and water in various proportions. From the specific gravity of the acid the relative humidity and the saturation deficit of the air in the desiccator were calculated.

Repeated experiments, using partly decayed berries received in shipment, as well as sound Klondikes and Missionaries inoculated with *Rhizopus nigricans*, proved that the fungus will destroy the strawberry ^{quickly} in a very dry atmosphere, even under concentrated sulphuric acid, as in a moist or saturated atmosphere. Certain differences in the attack of the fungus on the berry under various humidities have been noted (13). The important fact in this connection is that when the fungus is once inside the strawberry no amount of external drying is sufficient to stop its development. The moisture contained in the fruit will permit the fungus to grow sufficiently to destroy the berry.

TEMPERATURE RELATIONS.

The temperature relations of *Rhizopus nigricans* have recently been studied by two investigators. Hanzawa (8) studied the temperature relations of various species of *Rhizopus* and used these relations as criteria for separating the genus into sections. He places *Rhizopus nigricans* in the section characterized by having no growth at 37° C. (99° F.). He found that this species was able to grow and produce sporangia at temperatures as low as 8° to 10° C. (46° to 50° F.).

Miss Ames (1) included *Rhizopus nigricans* among the storage-rot fungi whose temperature relations she investigated. She found that at 9° to 10° C. (48° to 50° F.) some growth occurred, although at this temperature the fungus was unable to mature sporangia within one month. Maximum growth occurred at 36° C. (97° F.), good growth at 37° and 40° C. (99° and 104° F.), and no growth whatever

at 42° C. (108° F.) Miss Ames also studied the time required for the germination of spores at various temperatures and found that in general the length of time required for germination decreased with rise of temperature, being greatest, 200 hours, at 3° to 4° C., and least, 5½ hours, at 41° C.; no germination occurred at 42° C. The difference in maximum temperatures as determined by these investigators may be due either to their having different strains of the fungus or possibly to their having used different culture media. Miss Ames used *Rhizopus* from sweet potato grown on string-bean infusion; Hanzawa's temperature tests were made with the fungus growing on potato.

In the writers' experiments on the temperature relations of *Rhizopus nigricans* the fungus was grown on ripe strawberries and on white corn meal in flasks. The refrigeration plant used by Drs. Brooks and Cooley, of the Bureau of Plant Industry, in their studies of the storage rots of apples was used. This gives satisfactory constant temperatures at intervals of 5 degrees from 0° to 20° C. In addition, for other low temperatures use was made of an ice thermostat, and for the higher temperatures thermostats heated by gas burners were used.

Sound berries of the Missionary variety shipped from Plant City in commercial refrigerators were inoculated with spores and mycelium of *Rhizopus* and placed at temperatures of 0°, 5°, 10°, 15°, and 20° C. At the end of five days berries kept at 0° and 5° showed no growth of the fungus and were as sound and fresh in appearance and taste as when first placed in the refrigerator. At 10° C. there was no aerial growth of the fungus and only a very tiny decayed spot about the region where inoculation was made. Most of the berry at this temperature was still perfect in appearance and taste. Berries at 15° and 20° C. bore abundant fruiting hyphæ and were typical "leaks." "Leak" is a term applied to fruit destroyed by *Rhizopus* because of the collapse of the berries and the leakage of juice from the boxes. Cultures in corn-meal flasks at the same temperatures showed in five days no growth at 0°, 5°, or 10° C., but abundant mycelium with sporangia at 15° and 20°. At 15°, however, there was only about half as much aerial growth as at 20° and about half the sporangia were white and immature. At 20° the surface of the flask was covered with mature black sporangia. Similar flasks kept for five days at 1°, 2°, 4°, 6°, 8°, 11°, 14°, and 18° C. showed no growth up to 8°, slight growth with occasional sporangia at 11°, and fairly numerous sporangia at 14° C.

Berries inoculated as described were kept for two weeks at 0°, 5°, and 10° C. Those kept at 0° and 5° were apparently as sound as when placed in the refrigerator. At 10° the berries were somewhat softened, and there was a slight aerial growth of mycelium near the

point of inoculation. Several boxes of commercial berries kept at 10° C. for one week showed about the same proportion of decayed berries as similar boxes kept at room temperature for 12 hours. Very little work was done on the investigation of temperatures above 20° C. The fungus appears, however, to be able to mature a few sporangia with short stalks on ripe strawberries at 36° to 37° C. From these experiments it appears that a temperature of 10° C. (50° F.), or, better, 8° C. (46° to 47° F.), is satisfactory for preserving strawberries from this fungus for a week or more. The rate of growth of this fungus increases so rapidly with rise of temperature above this point that the importance of keeping the berries at this temperature is obvious.

In this connection it is of interest to note that Earle (4) in his shipping experiments found that 50° F. was satisfactory for shipping strawberries.

HOST RELATIONS.

From microscopic study (13) it is apparent that *Rhizopus nigricans* is unable to penetrate the sound epidermis of the strawberry. Additional evidence as to the correctness of this view is found in the results of experiments in which wounded and unwounded berries were sprinkled with spores of *Rhizopus*. The wounded berries in all cases rotted quickly and bore typical sporangia, while the unwounded berries remained uninfected.

Inoculation experiments in field and laboratory show that *Rhizopus* is able to grow in green strawberries and produce typical leak if the epidermis is wounded. On February 21, 1916, green berries shipped from Florida were wounded and inoculated with *Rhizopus*. Two days later all these berries had developed mature sporangia. Ten similar berries, unwounded, over which spores of *Rhizopus* were sprinkled showed no change. While still on the vines 100 green berries were wounded and inoculated with *Rhizopus* mycelium from a pure culture. All of these developed the typical *Rhizopus* rot, most of them before maturity.

OCCURRENCE ON OTHER PLANTS.

Rhizopus nigricans has been noted frequently as the cause of rot in various vegetables. Ehrenberg (5), in connection with his original description of the genus, mentions its occurrence on decaying fruits of *Cornus masculus*, *Morus alba*, and once on apple (*Pyrus malus*). Behrens (2) found it causing rot of tomatoes (*Lycopersicon esculentum*) and was able to produce decay by inoculation in pears (*Pyrus*), plums (*Prunus*), raspberries (*Rubus*), and currants (*Ribes*). Wormald (17) and Hanzawa (8) report it as causing a decay of tomatoes. In this country it is probably best known as causing a rot of sweet potatoes (*Ipomoea*), although Halsted (7)

found it to be the most important cause of decay of quince (*Cydonia*) fruit, Orton (11) reports it as causing a soft rot of white potatoes (*Solanum*), and Hawkins (9) corroborates the observations of Orton. The writers have also found this species on red raspberries in the Washington market.

This fungus may at times cause a serious rot of pears, and to some extent of peaches, as shown by the following manuscript note furnished by Mr. M. B. Waite:

In September, 1902, shipments of Kieffer pears from Patuxent (Woodwardville P. O.), Md., to the Washington, D. C., market suffered very severely from decay induced by *Rhizopus nigricans*. Pears of this variety had been shipped with success from 4-year-old trees in 1900 and from 5-year-old trees in 1901 by picking them hard and green, beginning about September 10 and continuing through the month. After picking they were stored in bins, usually for about a week, partly covered with canvas cloth. The layer of pears, about 2 to 2½ feet thick, colored up nicely without shriveling and brought a good price on the market.

Shipments started in this way in 1902, picked about September 10 and shipped a week later, began to arrive in good condition. Daily shipments were made, and a few days after the first arrived trouble was experienced with a soft rot, found on examination to be due to *Rhizopus nigricans*. The individual fruits attacked were completely disintegrated, those not attacked remaining sound.

About September 20, a carload of fruit was shipped in barrels and baskets. The barrels were of the open-head truck type, with cloth covers. The baskets were of the ordinary slatted, 4/8, 25-pound Delaware type. About half the fruit in baskets was salable at a reduced price, some of the baskets being one-third or one-half rotted.

The fruit in barrels, however, was almost a total loss. About 50 or 60 of these barrels were placed on arrival in the second story of a commission house, to allow them a few days to ripen, and the juice leaked freely out of the more open barrels through the floor and dropped down to the lower story. The tighter barrels became slightly swelled, so that they were water-tight, and on examination they were found to be partly filled with the liquefied contents, with a few perfectly sound pears floating or immersed in the liquid. The fruit was packed on one day, delivered to the city by rail on the afternoon of the following day, and hauled to the commission house. On the following morning the rot was found starting in strongly, and in another 24 hours the results already described appeared.

The fruit was thought to be fairly well handled by methods that had given good results in previous years, but the Kieffer pear is very hard and brittle, and the epidermis is easily ruptured by rubbing or scratching. The inability of the fungus to penetrate certain fruits is accounted for by their complete freedom from the slightest injury to the cuticle. Later pickings from the same orchard, with cooler weather and perhaps somewhat better handling, gave good results. Fruit picked and shipped green the first week in October stood the trip to Washington and was immediately placed in cold storage without any traces of *Rhizopus* rot. Shipments were made for 10 years following this without encountering this difficulty to any appreciable extent.

Occasionally trouble somewhat similar has been experienced to a minor degree in shipments of peaches. Last summer (1915), about August 15, a refrigerator carload of Belle peaches, shipped to the Washington market from Clarks Gap, Va., showed this type of rot before it was completely sold. The car opened up in good condition, and part of the fruit was sold the morning after

arrival in good order. Some of the remainder was held in the car two or three days and part of it at a commission house, and it deteriorated very rapidly, owing to the attacks of *Rhizopus nigricans*. The fruit leaked badly, many of the peaches becoming completely penetrated and overgrown by the rot fungus. In this case the fungus appeared to grow readily from one fruit to another, possibly through the stem end.

It is significant that in all cases where the rot caused by *Rhizopus nigricans* is described it is characterized by the loss of a large quantity of liquid from the decayed tissue. Behrens (2) and Wormald (17) speak of this in discussing the rot of tomatoes, Halsted (7) in quince, Orton (11) in potatoes, and Waite in pears and peaches.

The observations recorded above show that *Rhizopus* is the chief and in some sections practically the only cause of rot of strawberries in transit. They show that the percentage of moisture in the air makes no difference in the rate of growth of the fungus inside the berry. Also, that while the growth of *Rhizopus* is very slow at 10° C. (50° F.) or below, the rate increases rapidly with the rise of temperature above that point, so that at favorable temperatures a strawberry infected with *Rhizopus* is destroyed in a few hours. Microscopic studies by one of the writers (13), as well as inoculation experiments and field observations, indicate that *Rhizopus* does not usually penetrate the uninjured epidermis of the strawberry.

From this work it is apparent that no method of drying the air of the container in which the strawberries are shipped, by ventilation or otherwise, will retard the decay of the fruit once the fungus has entered, but that rot of strawberries in transit may be diminished greatly by reducing the amount of infection by *Rhizopus* or by keeping the berries at a low temperature from the time they are picked until sold. The importance of low temperature in shipping strawberries was demonstrated by Parker Earle during the period from 1866 to 1872 (3 and 4). Earle found that strawberries cooled to 50° F. in a specially constructed cooling house previous to shipment might be sent long distances in refrigerator cars in practically perfect condition.

PRESENT SHIPPING PRACTICES.¹

To appreciate the general lack of complete refrigeration and the importance of reducing infection by *Rhizopus*, it is necessary to know something of the methods of handling strawberries now in general use.

¹ Descriptions of the development of refrigerator transportation of truck produce were published in 1901 by F. S. Earle (3) and W. A. Taylor (15). Of particular interest in this connection are the descriptions (3, p. 444; 15, p. 575) of the early work of Parker Earle in shipping strawberries under refrigeration. So far as the writers have been able to learn, Parker Earle designed the first refrigerator chest for shipping strawberries by express and was the first to demonstrate the effectiveness of precooling. His letter (3, p. 444-445) places the beginning of this work about 1866, and it was mentioned by Holcomb in 1870 (10).

In most localities the berries are either shipped in the containers in which they are picked, without further handling, or emptied on tables, the culls removed, and the sound fruit repacked for shipment. The former method necessitates great care in picking; the latter method undoubtedly bruises the berries somewhat even when carefully done.

Practically all berries shipped from Florida are packed in quart cups, each cup "capped" or "plated"; that is, the top layer consisting of berries of uniform size placed snugly together with their tips all pointing in the same direction. Shipments from this State are made at a season when no other berries are in the markets and are intended to supply a demand for fancy fruit.

The strawberries are shipped in three ways. During the early part of the season most of them are shipped by express in iced containers, called pony refrigerators, which hold 64, 80, or occasionally 32 quarts each. From 75 to 250 pounds of ice is placed in an open pan in each refrigerator and the refrigerator tightly closed. In this manner berries are often shipped long distances, to New York, Boston, Philadelphia, Pittsburgh, Chicago, and other northern markets. Later in the season iced cars are shipped from the more important strawberry-growing centers, but the use of the pony refrigerator is at no time abandoned. Under favorable weather conditions many shipments from Florida to Washington, Baltimore, and other relatively near-by markets are made by express in open ventilated crates without refrigeration. The use of different methods of shipment increases the difficulty of controlling merely by refrigeration the growth of *Rhizopus* during transit and emphasizes the necessity of preventing the infection of the fruit. Experiments were performed to determine the relative importance of the various possible sources of infection.

In many strawberry-growing sections it is customary to mulch with hay, straw, pine needles, or other material to protect the fruit from dirt. In other localities this practice is not followed, and when the fruit is picked immediately after a rain or when wet with dew much sand or other dirt adheres to the berries. This fruit is sometimes shipped to market without cleaning, but usually an attempt is made to avoid or correct this condition. In some localities picking the berries early in the morning when wet with dew is avoided, and the dry sand is shaken off in the process of picking. In other places the fruit is emptied on tables covered with cloth and shaken gently, most of the sand being lost in this way. In central Florida, a region important for the earliness and length of its shipping season, it is customary to wash the berries when brought from the field. They are immersed for a few seconds in a tub of water, then either packed moist or spread on a cloth frame

and allowed to dry in the shade of the packing house or even in the sun.

SOURCES OF INFECTION BY RHIZOPUS NIGRICANS.

INFECTION IN THE FIELD.

Infection with *Rhizopus* apparently could occur either in the field before picking or in the packing shed. Microscopic examination of diseased fruits (13), as well as observations and inoculation experiments in the laboratory, the field, and the packing house, indicates that *Rhizopus* rarely, if ever, enters berries through the uninjured epidermis. The proportion of injured or wounded berries in a field usually is low. Some fruits, of course, are injured by insects or birds, but rapidly growing strawberries have a strong power of preventing infection by the quick covering of wounds with an impervious protective layer.

This was well illustrated in an inoculation experiment made in the field on February 23, 1916. One hundred sound berries of various ages from one to seven days before maturity were wounded with a sterile needle while still on the vines. One hundred similar berries were wounded in the same way, and a small quantity of dirt from underneath the plants was forced into each wound. One hundred wounded berries in another series were inoculated with mycelium from a pure culture of *Rhizopus*. These berries were picked when mature and their condition compared with that of 100 uninjured berries. No rot was apparent among the fruits merely wounded. All but two of the berries into which dirt had been introduced matured without showing any signs of infection; a callus layer underneath the wound was evident in each case. Two exceptions showed at the end of five days soft spots on one side of the wounds. All of the berries inoculated with *Rhizopus* mycelium developed into typical leaks in from two to four days, most of them before the maturity of the berry. Leaky berries are rarely, though occasionally, found in the field.

Similar experiments were performed with ripe berries at the time of picking and the berries shipped in iced containers to Washington. In this series some of the fruits were wounded also with pine needles from the mulch. Records taken after shipment showed the following percentages of fruit still sound: Unwounded, 72 per cent; wounded with sterile needle, 61 per cent; wounded with pine needles, 62 per cent; dirt introduced into wounds, 42 per cent. Those inoculated with *Rhizopus* mycelium had become a mass of rotten berries before reaching destination. Wounding the fruit with pine needles gave practically the same result as the use of a sterile needle. The introduction of soil into the wounds apparently induced con-

siderable decay, but none of the berries so treated developed into typical leaks within 48 hours after removal from the refrigerated container, and the presence of black dirt in the wounds was misleading and made the accurate sorting of these berries difficult.

The above experiments indicate that the fungus in question is not of primary importance as a field rot, that usually it does not enter the berries from the soil, and that in the localities investigated infection occurs at some time after picking.

UNSANITARY CONDITIONS USUALLY PREVAILING IN THE PACKING HOUSE.

Conditions in and around the packing house often are unsanitary, favoring the growth and distribution of *Rhizopus*, and the frequent handling and consequent bruising which the berries often undergo would seem to offer many chances for infection. The culls often are thrown on the ground near the packing house; various fungi, including *Rhizopus*, may be found fruiting on these discarded berries. Packing tables become soaked with strawberry juice and usually are not cleaned or disinfected during an entire season. When berries are washed, a few gallons of water are placed in a tub and used for all berries cleaned during the day. Fungus spores, soil, and other dirt soon accumulate in this wash water, and apparently might by this means be distributed generally over a large proportion of the fruit.

Conditions in packing houses and cars as regards infection from *Rhizopus* can be easily improved by the frequent use of hot water. The recent work of Thom and Ayers (16) shows that the spores of this fungus are easily killed by heat when wet, but are more resistant in dry air. *Rhizopus* spores (16, p. 159) were killed in 30 seconds at a temperature of 145° F. in milk, but survived a temperature of 200° F. when dry. It is probable, however, that even with the greatest care all sources of fungous growth and distribution can not be eliminated.

THE BRUISING OF BERRIES IN PACKING.

It has been shown that *Rhizopus* rarely, if ever, enters berries through the unbroken epidermis; care to avoid bruising is therefore of great importance. This fact was emphasized by an experiment in which sound berries were wrapped individually in tissue paper, carefully packed, and shipped to Washington. It was found that fruit so treated could be held at room temperature for a week or more after arrival without the appearance of decay, while similar berries packed and shipped in the commercial manner were badly rotted within 48 hours after reaching their destination.

Berries are injured to some extent every time they are handled or shaken. When possible, especially when shipments are made in car lots under refrigeration, it is preferable to ship in the containers in

which the fruit is picked without further handling. However, fruit shipped in crates without refrigeration or in pony refrigerators, as from Florida, usually suffers severely by careless handling at points of transfer. In these cases the close packing of the fruit to prevent settling has been found to be of much advantage. If packed too tightly or forced into place, the fruit is unnecessarily crushed and bruised. The aim of the best packers is to place the berries as closely as possible without crowding or injuring them.

DIRECT SOURCES OF INFECTION.

One experiment was conducted in which the berries were treated in various ways to obtain, if possible, some indication as to the most serious sources of infection with *Rhizopus* in commercial handling. Apparently sound berries were selected, and in order to accentuate the comparative value of the results obtained the epidermis of each berry (except in A and C, Table I) was broken with a sterile needle before other treatment. All berries were then packed similarly and shipped in small iced containers. The results of the experiment are given in Table I.

TABLE I.—*Infection of strawberries resulting from various methods of treatment.*

Treatment of fruit, if any.	Condition after arrival at destination (per cent).		
	Sound.	Soft spots.	Leaks.
A.—Sound fruit, not wounded.....	72	28	0
B.—Wounded with sterile needle.....	61	32	7
C.—Wounded with pine needles.....	62	35	3
D.—Washed in clean water.....	66	22	12
E.—Washed in water used in packing house.....	0	71	29
F.—Dirt forced into the wounds.....	42	58	0
G.— <i>Rhizopus</i> mycelium forced into wounds.....	0	0	100
H.—Washed in water containing spores from a pure culture of <i>Rhizopus</i>	0	0	100

Table I shows that injury with pine needles and washing in clean water did not injure the shipping qualities of the berries any more than did injury with the sterile needle. The contrast between the final condition of fruit washed in clean running water and that washed in the ordinary commercial manner was most striking. This preliminary shipment gave a valuable clue, which was followed in subsequent experiments. In all later shipments sound, unwounded berries selected individually by one of the writers or those selected by careful professional packers were used.

WASHING BERRIES.

The influence of washing upon the development of rot in strawberries was investigated. In each of a series of shipments made in small iced containers, commercial pony refrigerators, or ventilated

crates without refrigeration, some of the berries were washed in the tubs of water which had been previously used for the washing of several bushels of commercial berries, some were washed in clean running water, and the remainder were not washed. All washed berries were dried for a few minutes in the shade. They were then packed by professional packers (all berries in each shipment being packed by one operator) and sent to Washington, where records were taken upon a careful inspection of each berry. The results of these experiments are summarized in Table II.

TABLE II.—*Infection resulting from washing strawberries in a commercial manner.*

Treatment of fruit, if any.	Number of berries.	Sound after arrival.
Not washed.....	716	<i>Per cent.</i> 37
Washed in clean water.....	1,153	35
Washed in dirty water used in the packing house.....	1,067	17

The generally low average of sound fruit was due to the length of time the berries had been kept at room temperature after reaching their destination. In northern markets, however, one frequently finds berries which contain no higher proportion of sound fruit. The results given in Table II indicated that the commercial method of washing berries was injurious to their shipping qualities and also that this injury would be largely overcome by the use of clean water. The frequent changing of water in the tub usually would not be inconvenient in Florida, for wells and pumps often are located at or near the packing houses.

DRYING BERRIES AFTER WASHING.

As already mentioned, a few growers make a practice of packing their fruit wet, though most of them expose it to the air, either in the shade of the packing house or, more frequently, in the sun, until most of the water has evaporated from the surfaces of the berries. Experiments were undertaken to determine the relative effects of these different methods from the standpoint of inhibiting the growth of *Rhizopus* in the fruit.

When berries are dried they are spread upon cloth-covered frames or packing tables. These cloth covers usually are not renewed during a shipping season. Often they are soaked with juice from the strawberries, and it was suspected that they might serve as carriers of infection to fruit spread upon them. Numerous careful experiments for the determination of this point, however, gave

negative results, indicating that any increase of infection from this source is relatively unimportant.

In investigating the effect of drying the fruit after washing, a number of experimental shipments were made, the fruit being handled in the same manner as in the washing experiment already described except that part of the berries in each shipment were packed wet, while the remainder were partially dried, usually by exposure to direct sunlight for a few minutes. The results were conclusively in favor of packing the fruit wet. Taking the average of all these experiments, it was found that drying berries washed in clean water had reduced the proportion of sound fruit 36 per cent. Among those washed in dirty water the reduction caused by drying was even greater—43 per cent.¹ Table III summarizes the results of all experiments on drying the berries after washing.

TABLE III.—*Effect of drying strawberries after washing.*

Treatment of fruit, if any.	Packed without drying.		Packed after drying.	
	Number of berries.	Sound after arrival.	Number of berries.	Sound after arrival.
Not washed.....	1,939	<i>Per cent.</i> 50		<i>Per cent.</i>
Washed in clean water.....	2,886	48	2,881	30
Washed in water used in the packing house.....	650	33	1,144	19

In no case were these results reversed, though they differed in degree in the various shipments. These variations were correlated with differences in temperature when the berries were packed, the comparative benefit of wet packing being greater in those shipments prepared on very warm days than in those packed during cool, cloudy weather. Drying the fruit, even in the shade, proved injurious, though less so than exposure to direct sunlight.

The laboratory experiments already cited indicate that the rate of growth of *Rhizopus nigricans* increases very rapidly with the rise of temperature above 10° C. (50° F.). When infected berries are held for a few hours at a relatively high temperature, for instance, 30° C.

¹ Smith and Goodman, of the Department of Agriculture of British Columbia, have conducted experiments upon the fanning of strawberries before shipment. They report (Winslow, R. M. Report of horticultural branch, 1914. In 8th/9th Rpts. Dept. Agr. [Brit. Col.], 1913/14, p. 84. 1915.) that berries dried for an hour in a strong current of air from an electric fan carry to market in better condition than those shipped even slightly wet. Though not so mentioned in their report, this operation would have the effect of lowering the temperature of the berries quickly and considerably by increasing the rate of evaporation of the water from their surfaces. It would thus be, in effect, a precooling process, allowing the berries to be placed in the car at a relatively low temperature if loaded at once; if, after fanning, however, the fruit were hauled several miles to the station during hot weather, much of the benefit of rapid drying would be lost.

(86° F.), the fungus develops so rapidly in their tissues as to cause them to collapse. The growth of the fungus may be checked by lowering the temperature, but with ordinary refrigeration growth will not entirely cease, and it may continue sufficiently to cause the berries to soften in transit; it will in any case resume rapid development whenever the temperature is again raised, as when the berries reach their point of destination. If infection has occurred, a difference of a few degrees in the temperature of the berries, maintained for several hours, will make a decided difference in the length of time before rot becomes apparent. This accounts for the harmful effects of drying the berries.

Dry berries remain at air temperature until placed in iced cars or other refrigerated containers, usually a period of several hours. During part of this time the crates are often exposed to the sun or covered with a dark cloth. When berries are immersed for a few seconds in water their temperature is lowered somewhat. Subsequent evaporation from their surfaces results in still further cooling. If they are packed immediately after washing, evaporation continues slowly and exerts a cooling effect for several hours, usually until the berries are placed under refrigeration. When berries are being loaded into cars in the afternoon, several hours after picking, the difference in temperature between unwashed fruit and that packed wet can be readily felt with the hand. When, after washing, the berries are dried for a few minutes in the shade, the water evaporates before packing, and they lose the continued cooling effect of prolonged evaporation. If they are exposed to direct sunlight there is the added disadvantage of a further rise in temperature. The beneficial effect of packing the berries wet is greatest, of course, when the temperature of the air is highest.

Professional packers claim that berries are softened by washing and must be handled with great care to avoid bruising if packed while wet. This probably is true, but it is more than compensated for by the cooling of the fruit.

Exposure to sunlight, unless very brief, has the further undesirable effect of giving the berries a dull appearance. Heating unwashed berries by exposure to the sun increases rot, but not so markedly as with washed berries. This is illustrated by an experimental shipment prepared at Lakeland, Fla., on the morning of March 22, 1916, a clear, warm day. Sound berries of the Missionary variety were used. After treatment they were packed by a professional packer, carried to the railroad station at noon, and shipped to Washington in a ventilated crate without refrigeration. They were three days in transit. Their condition on arrival is shown in Table IV.

TABLE IV.—*Effect of drying or heating strawberries.*

Treatment of fruit, if any.	Unwashed fruit.		Washed fruit.	
	Number of berries.	Sound after arrival.	Number of berries.	Sound after arrival.
Packed without drying or heating.....	396	<i>Per cent.</i> 72	352	<i>Per cent.</i> 69
Exposed to air (21° C., 70° F.) in shade of packing house.....	430	64		
Exposed to sunlight (30° C., 86° F.).....	412	56	416	47
Spread on table covered with black cloth and placed in sun; temperature 36° C. (97° F.).....	473	37		

Observations at points of shipment and destination show that car lots of berries picked and shipped on very warm days under similar conditions of transit do not arrive at northern markets in such good condition as those shipped during cooler weather. This further illustrates the fact that the temperature of the berries from the time they are picked until placed under refrigeration influences their shipping qualities.

A final series of experiments was undertaken to substantiate further the previous results in regard to the effect of washing fruit in clean water and drying before packing. In this series, as before, shipments were made in small iced containers, commercial refrigerators, and in ventilated crates without refrigeration. Table V summarizes the results of these shipments. They agree with the former experiments in showing the harmful effects of drying and emphasize the benefit derived from packing the fruit wet, for berries treated in this manner arrived at their destination in even better condition than those not washed.

TABLE V.—*Effect of washing strawberries in clean water and of subsequent drying.*

Treatment of fruit, if any.	Number of berries.	Sound after arrival.
Not washed.....		<i>Per cent.</i>
Washed in clean water and packed wet.....	3,027	46
Washed in clean water and dried before packing.....	2,809	51
	2,826	32

SUMMARY.

The conclusions given here are drawn chiefly from field studies and experiments made in Florida and Washington in the winter and spring of 1916 and in Louisiana and Chicago in 1917.

The deterioration of strawberries in transit may be due to the condition of the berries at the time of shipment or to inadequate trans-

portation or refrigeration facilities, but it is often induced by fungi, chiefly *Rhizopus nigricans*.

Rhizopus causes the softening and rapid collapse of strawberries, accompanied by the escape of much juice.

Berries though bearing the spores of Rhizopus when shipped may still, with proper handling and refrigeration in transit, reach the market in good condition. The fungus is not able to penetrate uninjured epidermis, but enters readily through wounds in either mature or green berries.

Rhizopus has not been found of primary importance as a cause of field rot, but usually develops in berries at some time after they are picked.

The humidity of the air has no perceptible influence upon the rate at which *Rhizopus nigricans* rots strawberries.

The growth of *Rhizopus nigricans* is very slow at 10° C. (50° F.) or below, but increases rapidly with the rise of temperature above that point. Therefore the proper cooling and refrigeration of the berries from the time they are picked until marketed will reduce the losses from this rot.

Since the diversity of shipping practices does not always permit such complete refrigeration, the reduction of infection by means of sanitation and careful handling is important.

The conditions at the packing houses are frequently unsanitary, affording favorable opportunities for the growth of Rhizopus, and bruising the fruit during handling allows infection to take place. The packing houses and tables should be kept clean. Injury to the fruit should be avoided by care in handling, or preferably, by the elimination of all unnecessary handling.

Washing berries in water in which dirt has accumulated injures their shipping qualities.

The temperature of the berries during the time between picking and shipping has an important influence upon the later development of rot.

Drying washed berries, especially by exposure to sunlight, increases decay, because the subsequent exposure of the dry berries to prevailing high air temperatures favors the development of Rhizopus within their tissues. The higher shipping quality of fruit packed wet seems to be due to the facts that the temperature of the fruit is lowered by washing in cold water and that by prolonged evaporation the berries are kept cool for a considerable time, during which they may be hauled to the station and placed under refrigeration.

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BULLETIN No. 532

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Engineering
LOGAN WALLER PAGE, Director



Washington, D. C.

PROFESSIONAL PAPER.

October 13, 1917

THE EXPANSION AND CONTRACTION OF CON- CRETE AND CONCRETE ROADS.

By A. T. GOLDBECK, *Engineer of Tests*, and F. H. JACKSON, Jr., *Assistant Test-
ing Engineer*.

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Observation of concrete roads shows that most of the irregularities of wear make their initial appearance at expansion joints and at transverse and longitudinal cracks. Soon after a crack is formed traffic begins to batter down the edges, and unless immediate and effective maintenance measures are adopted, each succeeding vehicle will act with greater destructive effect. Under such conditions and without proper maintenance, little time elapses before depressions are formed in the road surface, which lessen the life of the road and render it decidedly unpleasant to the fast-moving traffic generally carried by concrete roads. Improperly maintained expansion joints wear in a manner similar to cracks, and the cost of their maintenance is dependent upon their frequency.

Cracks result when the tensile strength of the concrete has been exceeded, or compression cracks may be caused in rare instances by excessive expansion without proper provision for such a movement. Tension may occur in a concrete pavement as the result of settlement or upheaval, in which case the pavement is stressed as a slab, and, if overstressed, will crack on the tension side. Most transverse cracks, however, are caused by contraction due to two principal phenomena: 1, decrease in temperature; 2, drying out of water from the concrete.

An extended series of laboratory and field tests was begun in 1910 by the Office of Public Roads to make a close study of expansion and contraction movements of concrete pavements. These included detailed attention to the spacing, design, and movement of expansion joints. It is the purpose of this bulletin to present the results of these experiments in the hope that they will be of some value to those interested in work of this nature. No attempt will be made herein to apply the results obtained to the practical side of road construction, although certain broad conclusions will be drawn from the results which will be available for immediate application by the engineer.

LABORATORY MEASUREMENTS OF EXPANSION AND CONTRACTION.

It has been established by other investigators¹ that concrete expands on being heated and contracts on cooling by an amount differing very little from that of steel. A coefficient of 0.0000055 per degree Fahrenheit seems to express accurately the effect of temperature. Therefore, with change in temperature of 100° F., a 100-foot length of concrete road, if unrestrained by friction at the base, would expand or contract $0.0000055 \times 100^\circ \times 100 \text{ feet} = +0.055 \text{ feet}$ or 0.66 inch. This phenomenon alone, without considering any other influences, probably accounts in many instances for the cracking of concrete pavements.

In view of the probable reliability of the already established temperature coefficient of expansion, all efforts of the laboratory were directed toward obtaining the change in length of concrete due to other causes. It has been shown, originally by Bauschinger and subsequently by other investigators, that both neat cement and mortar contract to a considerable degree upon hardening in air, while, on the other hand, they show considerable expansion when placed in water. Some of the values of contraction of neat cements and mortars, reported by White in the 1911 Proceedings of The American Society for Testing Materials, are as follows:

Shrinkage of neat cement kept in air.

	Per cent.
7 days (average of 6 specimens)	0.109
28 days (average of 6 specimens)	.190
6 months (average of 6 specimens)	.236
1 year (average of 5 specimens)	.270
2 years (average of 5 specimens)	.289
4 years (average of 5 specimens)	.322

¹ Kellar, "Volumänderungen von Cementen verschiedener Mischung bei wechselnder Temperatur und wechselnder Feuchtigkeitsgrad," *Tonind. Zeit.* 19, 469 and 487, 1894.

Pence, W. D., "The Coefficient of Expansion of Concrete," *Eng. News*, 46,380 (1901).

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Rudeloff and Siegler Schmidt, "Untersuchungen über die Längenänderungen von Betonprismen beim Erhärten und in Folge Temperaturwechsel," *Deutsch. Ausschuss für Eisenbeton*, Heft 23, 1913.

According to these figures, neat cement shrinks about $2\frac{7}{8}$ inches in 100 feet when kept in air six months, and in four years the shrinkage, due merely to the drying out of the moisture, amounts to almost 4 inches in 100 feet. Mortar mixed in the proportions of 1 part of cement to 3 parts of sand, when allowed to harden in the air, shrinks, according to White's results, from 0.08 per cent to 0.1 per cent. These figures confirm in a general way the previously published figures of Bauschinger and others.

As neat cement and mortar were known to have this physical characteristic of expanding and contracting, depending upon their moisture content, it was considered reasonable to suppose that concrete, too, would show the same general behavior. The following laboratory tests were made on concrete to determine the amount of movements produced by the drying out and absorption of water. These movements, combined with temperature movements, probably account for most of the expansion and contraction of concrete pavements, and a knowledge of their values is of assistance in the design of expansion joints.

DESCRIPTION OF EXPANSION AND CONTRACTION SPECIMENS.

White and the earlier investigators made tests on the change in length of neat cement and mortar with specially designed micro-meters on very small specimens, White's being only 4 inches in length. Obviously it would be impossible to use such small test pieces as these to determine the expansion and contraction of concrete containing coarse aggregates, and the type adopted was a column 8 inches square and 5 feet high. The column form of specimen was used to permit the free expansion of one end, in this way preventing friction from affecting the accuracy of the measurements.

PREPARATION OF SPECIMENS.

All concrete mixtures were proportioned by weight with a standard brand of Portland cement, Potomac River sand, and crushed gneiss or gravel. The cement was normal and passed the specifications of the American Society for Testing Materials. The sand was coarse and clean and considered a good grade of concrete sand. All concrete was hand mixed and was made of various consistencies. The specimens of very dry consistency required hard tamping to consolidate the concrete in the mold, while those of wet consistency were made simply by puddling the mixture in place. The amount of water used for the dry mixtures was about 8.5 per cent of the weight of dry materials. For the wet mixtures from 10 to 12 per cent was used.

MEASURING APPARATUS.

Referring to figure 1, it will be noted that to measure the change in length of the specimen, crossbars of steel one-half inch square were cast in the concrete. They were placed 50 inches apart, center to center, and this was considered the gauge length of the measurements.

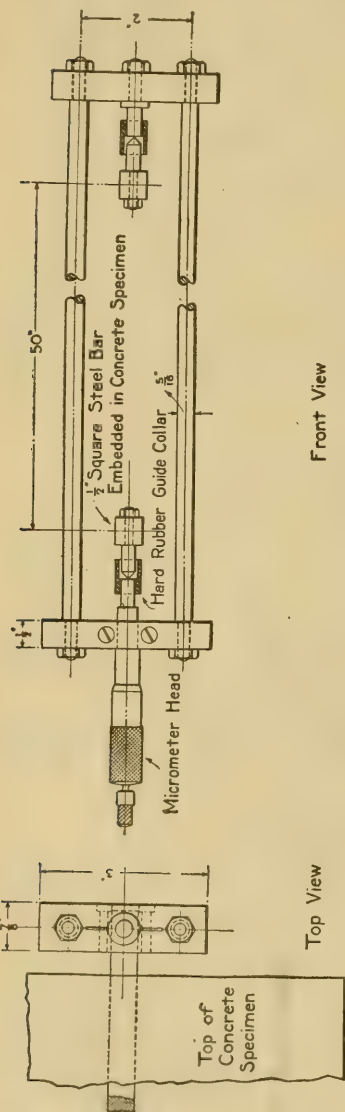


FIG. 1.—Apparatus for measuring expansion and contraction.

On each end of these bars a plug of steel with a rounded conical point was fastened, and micrometer measurements were taken between these points on each side of the specimen. Two readings were taken, so that unequal movements of the two sides of the specimen could be cared for by averaging the readings, thus obtaining expansion or contraction along the center line.

For obtaining the readings a special form of instrument (fig. 1) was designed and constructed in the laboratory. It consisted of a micrometer head reading to 0.0001 inch mounted at the end of a steel yoke. This yoke contained two steel rods five-sixteenths of an inch in diameter bolted to two end crosspieces, one holding the micrometer and the other a flat-ended steel pin. In taking measurements the flat-ended pin was held in contact with the lower conical point of the specimen, and the micrometer was screwed down to contact with the upper conical point. During the initial readings electrical contact was used in order to read the micrometer to the nearest 0.0001 inch. This, however, was discarded when it was found that readings of sufficient accuracy could be attained without it. In order that

any change in the measuring instrument, due to wear or accident, might be detected, readings were taken repeatedly on a steel gauge bar hung from the specimen. Before any reading was made the instrument was hung alongside the specimen for a sufficient time to

bring it to constant temperature as determined by a thermometer likewise hung beside the specimen. A thermometer was inserted also in a horizontal orifice in the middle of the concrete specimen, and the temperature was noted at each reading. Finally, all readings were corrected to eliminate the effect of differences in temperature, whether due to chemical activity of the cement in hardening or to external changes. In figure 2 is shown a specimen with measuring instrument attached.

RESULTS OF EXPANSION AND CONTRACTION MEASUREMENTS.

The results of these laboratory measurements are best seen by reference to the following curves:

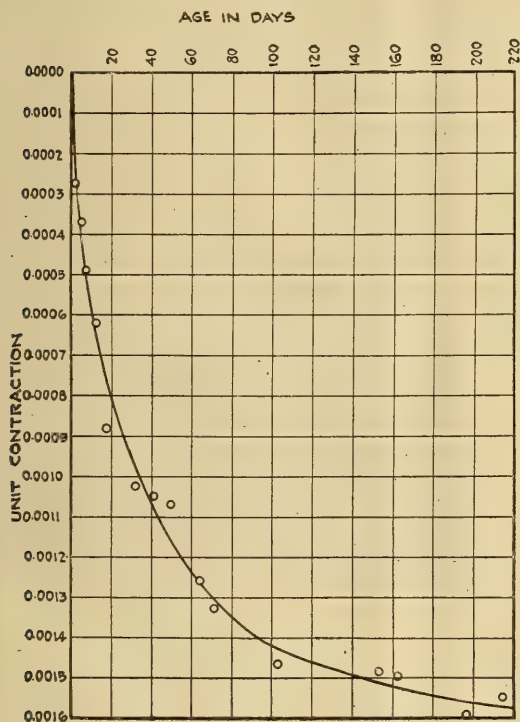


FIG. 3.—Neat cement, stored in air.

takes place immediately, and at the age of 6 months a total shrinkage of 0.155 per cent, or $1\frac{1}{8}$ inches, in 100 feet took place. This is much less than the results of White, who observed a shrinkage of 0.236 per cent, or $2\frac{1}{8}$ inches, in 100 feet.

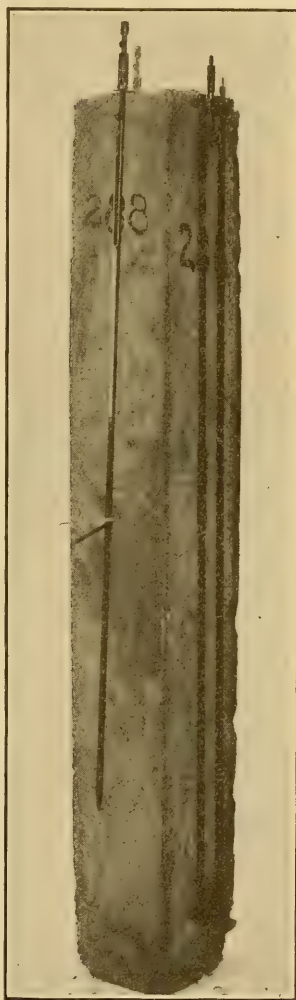


FIG. 2.—Specimen and apparatus for measuring the expansion and contraction of concrete.

NEAT CEMENT, STORED IN AIR.

On figure 3 is shown a typical shrinkage curve of neat cement stored in the warm, dry air of the laboratory. It will be seen that shrinkage

1:2 AND 1:3 MORTAR, STORED IN AIR AND ALSO IN WATER.

The shrinkage of mortar when stored in air and the expansion when stored in water are shown clearly on the diagrams in figure 4. Note that the changes are

somewhat greater in the 1:2 than in the 1:3 mortar. The shrinkage of air-cured 1:3 mortar which has been allowed to dry out is approximately 0.078 per cent at the age of 6 months, and that of 1:2 mortar at the same period is 0.085 per cent, which figures are quite like those of other investigators. It will be noted that both the 1:2 and 1:3 mortars have expanded when immersed in water, and at 6 months the values for the respective mortars are 0.015 per cent for 1:3 and 0.025 per cent for 1:2.

CONCRETE STORED IN AIR.

On figure 5 is shown the behavior of concrete when it is allowed to dry out immediately after molding. The specimens are 1:2:4 and 1:3:6 mixtures of very wet and of very dry consistencies. It is seen that contraction takes place almost immediately, due to drying out of the water, and at the age of 1 week the approximate contraction is from 0.01 to 0.03 per cent, or from 0.0001 to 0.0003 inch per inch of length. If the modulus of elasticity of concrete is assumed to be 2,000,000 pounds per square inch in tension, the tensile stress that would be developed by a contraction of only 0.0001 inch per inch of length would be 200¹ pounds per square inch. Unless free contraction of the concrete were provided some of this stress would be developed and cracking surely would result, as the tensile strength of the concrete then would be exceeded. These curves represent merely the contraction due to change in moisture, and all temperature effects are eliminated.

1:2:4 AND 1:3:6 CONCRETE, ALTERNATELY WET AND DRY.

The curves on figure 6 show very clearly the effect of changes in moisture content on the change in length of concrete. The specimens were mixed in different proportions and consistencies, and all were kept wet for 15 days after pouring the

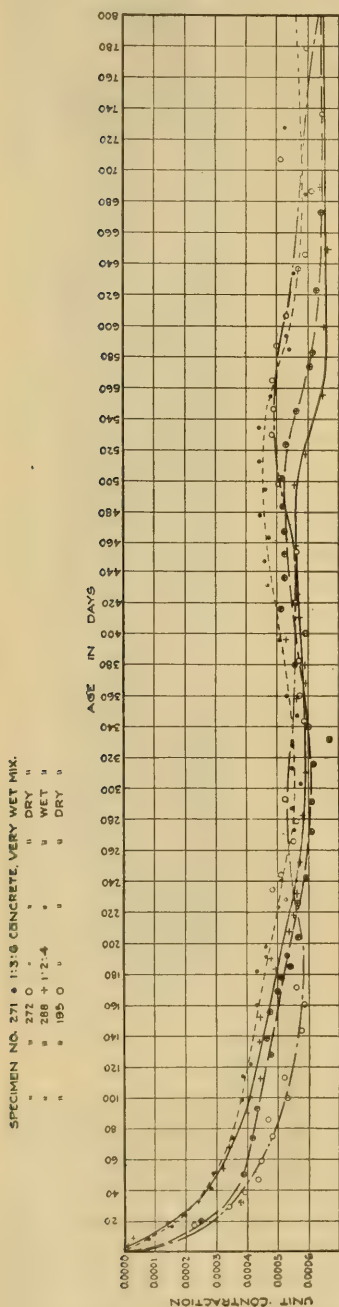
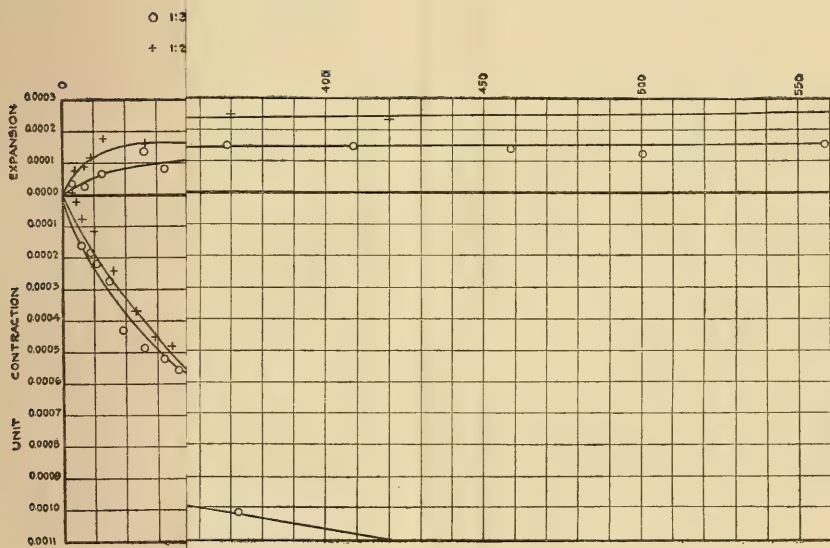


Fig. 5.—Concrete stored in air.

¹ The "flow" effect of concrete probably will decrease this figure. This is mentioned later.



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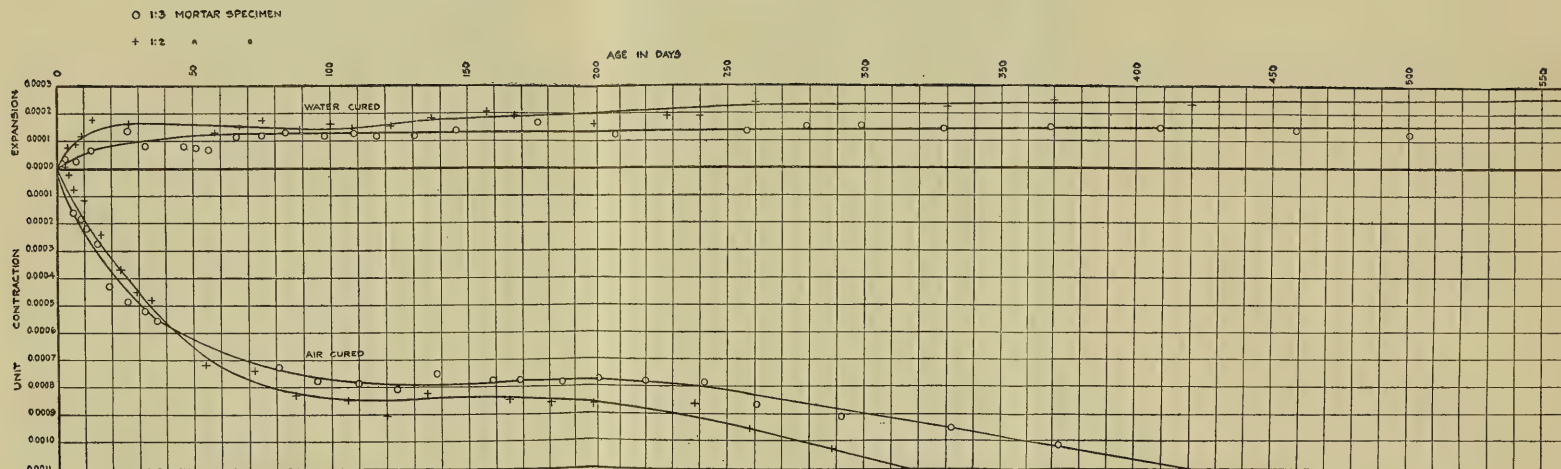
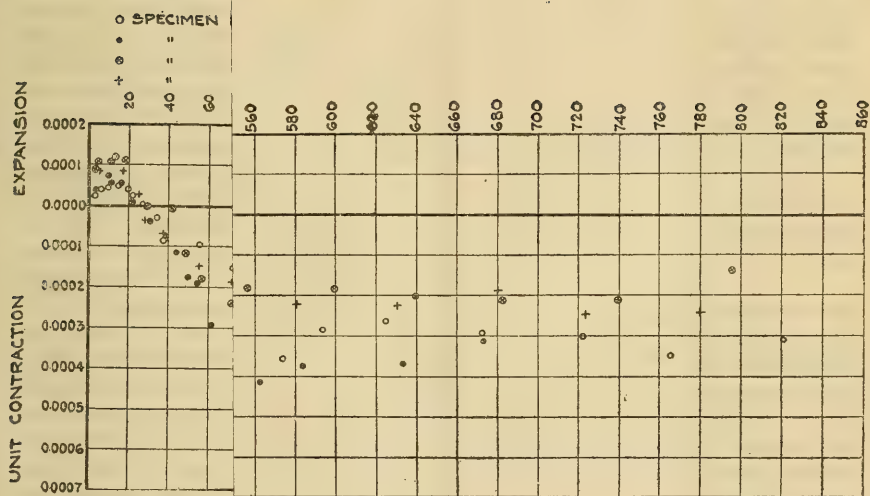


FIG. 4.—1:2 and 1:3 mortar, stored in air and also in water.



E WHERE SPECIMENS WERE IMMersed IN WATER.
tely wet and dry.

concrete. This was done by covering them with burlap and keeping the burlap wet constantly. As soon as the concrete had become sufficiently hard, or in most instances not over two days after pouring, the forms were removed and initial readings of the specimens were made.

Referring to the curves, which are plotted with age in days as abscissas and with unit expansions and contractions as ordinates, note that during the first 15 days when the specimens were kept wet there was a continuous expansion, the maximum amounting to about 0.0001 inch, or 0.01 per cent. At the end of 15 days the specimens were permitted to begin drying out, and the effect of this drying is seen on the curve, which drops, or shows contraction, immediately. The specimens continued to contract for a period of practically one year, when the maximum contraction was about 0.0006 inch, or 0.06 per cent. After the specimens were more than a year old (460 days and 540 days) they again were kept continually moist and immediately started to expand, but did not regain their former length. The amount of expansion was roughly 0.0004 inch per inch of length, or about 0.0002 inch short of their original length. Note that during the first few days after reimmersion these specimens expanded only from 0.0001 to 0.0002 inch per inch of length and their subsequent expansion was slow, requiring several months to reach the maximum. The above specimens were dried in the rather dry and warm atmosphere of the laboratory, and therefore were almost as dry as it was possible to make them. It will be noticed that there is no great difference in the contraction and expansion of the different mixtures tested, whether they were 1:2:4 or 1:3:6, very wet or very dry. Comparing figure 5 with figure 6, it will be noted that the ultimate contraction is about the same whether or not the concrete was subjected to an initial period of wetting.

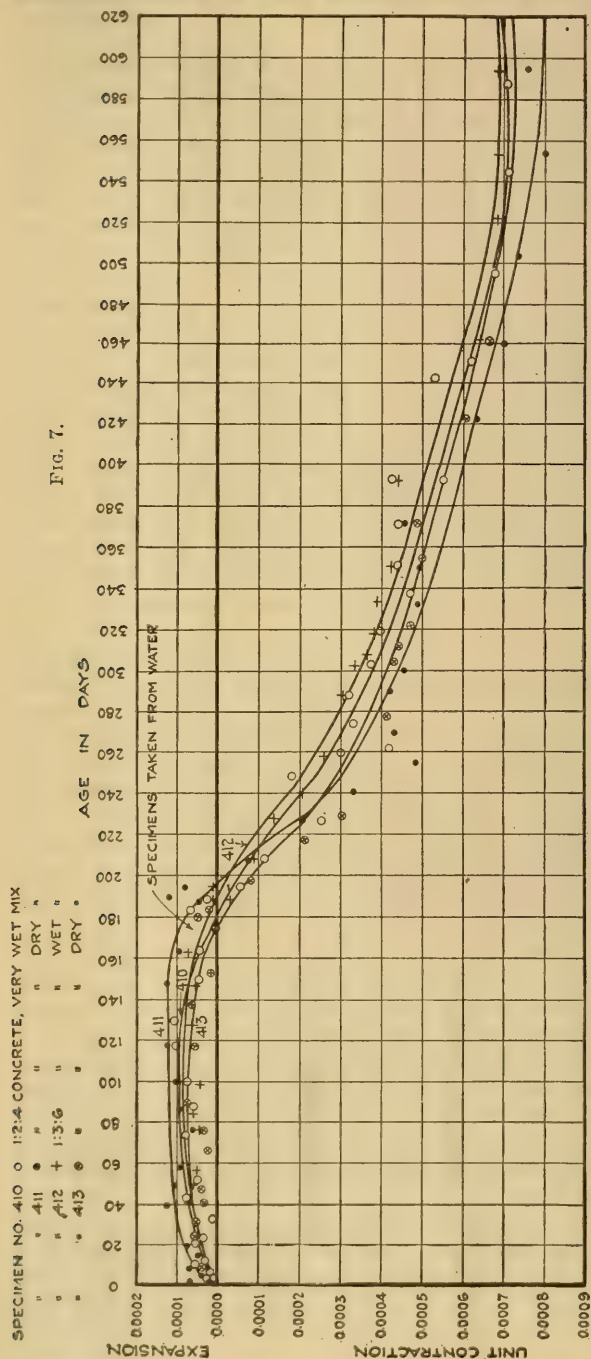
Let it be supposed that the ends of a concrete construction are immovable and that it is subjected to extremely dry conditions, so that it will shrink 0.0006 inch per inch of length. Then, if a modulus of elasticity of 3,000,000 pounds per square inch is accepted as correct, the tensile stress produced will be $3,000,000 \times 0.0006 = 1800$ pounds per square inch. Obviously, under such conditions as these, concrete must crack, since a stress of only 200 pounds per square inch is not far from the maximum tensile strength of concrete. There are, however, very few concrete structures that are subjected to the degree of drying out suffered by the specimens reported, and the results are given merely to show what can and does happen to concrete under conditions favorable to its thorough drying.

These curves show quantitatively what occurs in a concrete pavement just after it is laid and demonstrate the efficacy of the practice of keeping the concrete wet for a short period after pouring. The curves show that concrete remains expanded as long as it is wet and contracts as soon as it begins to dry out, with the consequent tendency to form cracks. In a concrete pavement, where there is always some restraint due to friction at the base, any tendency toward shrinkage will be resisted, and tension will be developed. In the earlier stages of hardening the tensile strength of concrete is very low, and consequently a very minute shrinkage may produce cracking, irrespective of the presence of expansion joints.

A consideration of the excessive shrinkage of concrete due to complete drying out, with a resulting hazard of overstress in tension, shows the great necessity for maintaining concrete structures in a moist condition for a few weeks after pouring. By this practice it is seen that they may be kept expanded, and, therefore, under small compressive stress. When they do dry

out, after several weeks, they shrink and develop tension, but they are then somewhat fortified by their maturity and are better able to resist the tensile stresses developed. The

FIG. 7.

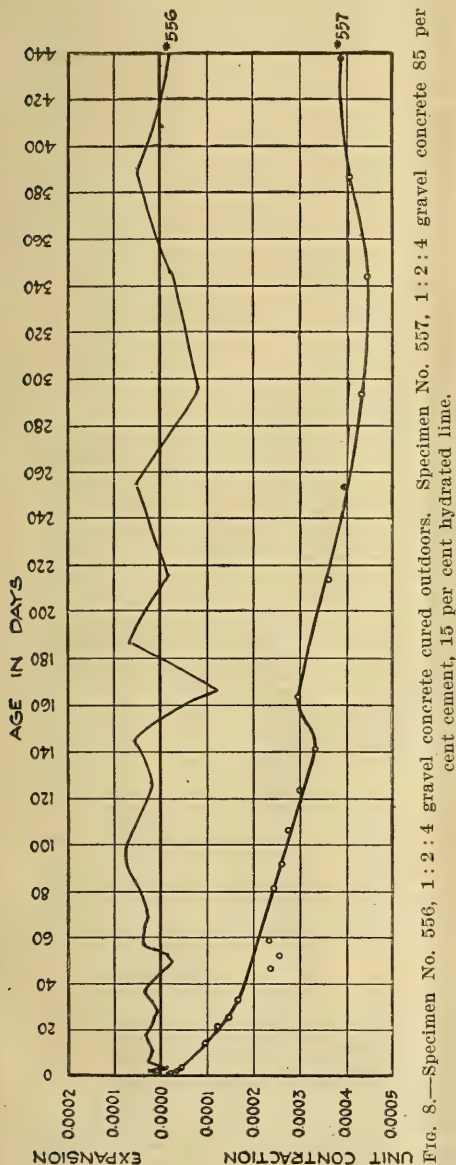


practice of keeping concrete wet must be emphasized from this standpoint, as well as from the fact that by so doing a more complete hydration of the more sluggish particles of cement is effected and the strength increased somewhat thereby. The practice of subjecting the concrete to an initial period of wetting can not wholly prevent cracking, but it does aid in decreasing the number of cracks that form in concrete pavements.

1:2:4 AND 1:3:6 CONCRETE; LONG INITIAL WETTING.

On figure 7 are shown four curves giving the expansion and contraction of 1:2:4 and 1:3:6 concrete of very wet and very dry consistencies. These specimens differ from the others in that they were kept in water for a period of about six months, then removed and allowed to dry in the warm, dry air of the laboratory. Note that concrete under constantly moist conditions maintains almost constant expansion while it is moist, and that the amount equals approximately 0.0001 inch, or 0.01 per cent. Theoretically, when the ends of a concrete structure are restrained from movement, this would produce a compressive stress of 3,000,000 pounds per square inch, multiplied by 0.0001 inch, or 300 pounds per square inch, provided stresses can be figured in this

way and are subjected to no other influences. Recent researches¹ have shown that under constant stress concrete exhibits a slow yielding, or "flow," making the deformation produced by constant stress very much greater than that produced by a static stress of short duration. In the curves on figure 7 it is



seen, again, that there is very little difference between the contraction and expansion of 1:2:4 and 1:3:6 concrete, whether wet or dry. Apparently there is not enough difference in the degree of richness of the mixture to cause a difference in the contraction and expansion of concrete. The maximum contraction obtained in this set of experiments was about 0.0008 inch per inch of length.

GRAVEL CONCRETE, STORED OUT OF DOORS.

On figure 8 is shown the effect of exposure to the atmosphere of a specimen made of 1:2:4 gravel concrete. This specimen was stored in a vertical position out of doors at a place where it was in shade for perhaps three or four hours every day. No effort was made to protect it from rain or sun. This curve, like the preceding ones, simply shows the effect of moisture, all temperature effects having been eliminated. It is seen that there has been but very little change in the length of the concrete due to moisture changes in the specimen. This seems reasonable to expect in a specimen cured out of doors, as the alternate wetting and drying to which it was subjected, due to changes in the weather, occurred with such frequency that there was little chance for moisture changes to be effective, and it has been pointed out already that large changes in length, due to moisture changes, are apt to be slow and progressive, although changes of 0.0001 to 0.0002 inch per inch of length may

occur in the course of a few days. The influence of moisture on this specimen cured out of doors probably is somewhat typical of the behavior of concrete in roads that have a well-drained subbase.

¹ "Flow of Concrete under Sustained Loads," by E. B. Smith, Proceedings of American Concrete Institute, 1916.

GRAVEL CONCRETE WITH HYDRATED LIME, STORED IN AIR.

Curve 557 on figure 8 shows the contraction of a 1:2:4 gravel concrete specimen in which 15 per cent of hydrated lime was substituted for cement. This specimen was cured indoors and allowed to dry out immediately after molding. Here again, as in the case of the ordinary concrete specimens, we have a progressive contraction, the maximum amount being about 0.00045 inch. This is somewhat less than in the specimen untreated with hydrated lime. As but one specimen was measured, no claim can be made that the hydrated lime aided in decreasing the contraction.

TAR-COATED SPECIMEN.

It is reasonable to expect that any application of more or less waterproof material to the surface of the concrete will greatly retard the absorption of moisture, or, if the concrete be already wet, will prevent it from drying out rapidly. In order to determine the effect of such a coating on the change in length of concrete, a mixture of 1:2:4 concrete, having a crushed gneiss aggregate, was prepared, and measurements were started two days after pouring. It was then immersed in water and the measurements continued. At the end of 13 days the specimen was removed from water and, after surface drying for one day, a hot application of vertical retort tar was made. Note that after 13 days' expansion continued slightly, although the specimen had been removed from the water and coated with tar, while at the end of about 30 days this expansion ceased and a slight contraction began. However, the specimen was still somewhat expanded up to the end of 150 days, after which it contracted very slowly. The tar coating evidently served to retain the moisture in the concrete for a considerable length of time and thus kept it expanded.

REINFORCED CONCRETE SPECIMENS.

Four specimens were made up of 1:2:4 gravel concrete containing 0.61 per cent, 1.2 per cent, and 1.8 per cent of steel. These specimens were allowed to dry out in the air of the laboratory, and measurements were taken at frequent intervals. The plain gravel specimens showed a maximum contraction of only 0.035 per cent at the age of 6 months, as compared with 0.06 per cent for the crushed gneiss specimens previously reported. This difference in contraction is not due necessarily to the different aggregates. The specimens containing 0.61 and 1.2 per cent steel showed a contraction of only 0.02 per cent,

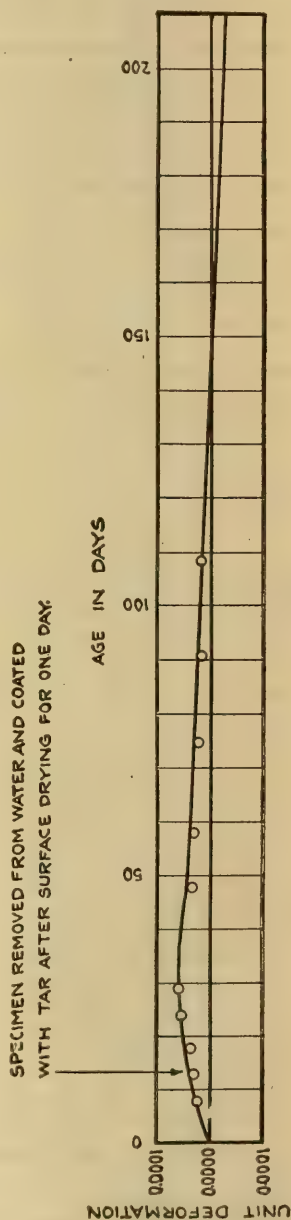


Fig. 9.—Tar coated specimen.

while the specimen containing 1.8 per cent steel contracted less than 0.01 per cent, or about one-fourth of the contraction of the plain concrete specimen.

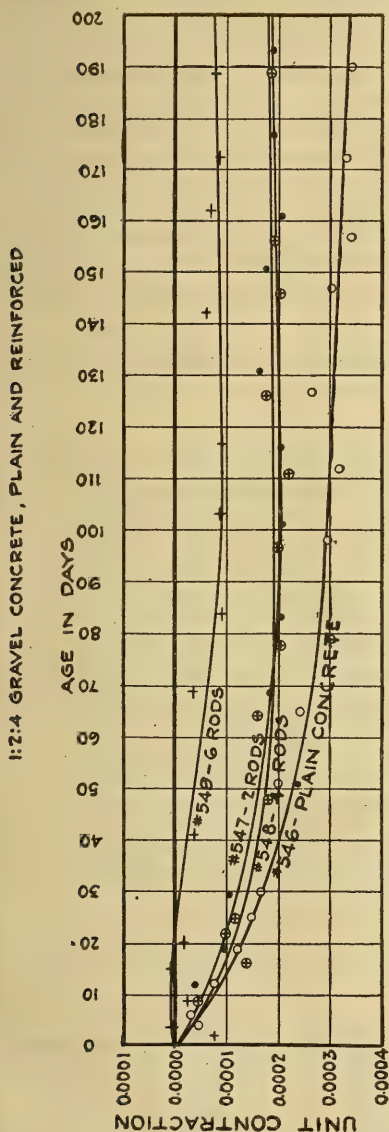


Fig. 10.—Effect of reinforcement on expansion and contraction.

If there were perfect bond between the concrete and the steel, this amount of shrinkage in the concrete would produce a stress of about 3,000 pounds per square inch in compression in the steel reinforcing of specimen No. 549, and about 7,500 pounds per square inch in specimens Nos. 547 and 548. The more concrete is restrained from shrinking, the greater will be the tensile stress induced by the compression in the steel. The specimen containing 1.8 per cent of steel contracted, roughly, 0.0001 inch per inch of length, while the plain, and therefore unrestrained, specimen contracted 0.00035 inch. In other words, the steel prevented the concrete from contracting by an amount equal to 0.00025 inch per inch in length. Assuming the modulus of elasticity of this concrete to be 3,000,000, the tensile stress produced by 0.00025 inch elongation would be 3,000,000 multiplied by 0.00025, equals 750 pounds per square inch, which stress, if it actually existed, would, of course, surely produce cracking of the concrete. If cracks were present in the specimens, they were not discernible, but they usually would be very small, and, moreover, it is probable that the slow flow of concrete previously mentioned took place under the extremely gradually applied load, making the induced tensile stress very much smaller than the calculated amount. Reinforcing, it is seen, does not prevent the contraction of concrete due to the drying out of the moisture, and in view of the fact that steel and concrete have very nearly the same coefficient of expansion and contraction, the steel can not aid in any way in preventing changes due to tempera-

ture. Reinforcing can not prevent the cracking of concrete, but it does serve the purpose of holding the cracks together and keeping them exceedingly minute.

SPECIMEN REINFORCED ON ONE SIDE.

If a concrete road be reinforced with steel placed either near the top or bottom surface, any shrinkage resulting from drying out necessarily must be unequal at the two surfaces because of the restraining influences of the steel. To show the relative amounts of this shrinkage a specimen was made of 1:2:4 concrete, reinforced by two $\frac{1}{2}$ -inch round rods with their centers placed 1 inch

from the side of the 8 by 8 inch column. The curve on figure 11 was obtained partly by measurement and partly by theory, assuming that the deformations from the reinforced side to the plain side varied as the ordinates to a straight line. This assumption has been shown to be true a number of times in the cases of beams subjected to bending stresses. Note that the steel seems to have had a bending effect on the specimen, the unreinforced side shrinking much more than the reinforced side. The amount of shrinkage on the plain side of the column at the end of one year amounted to approximately 0.1 per cent; that of the steel amounted to 0.03 per cent. Any such shrinkage as this would tend to cause compressive stresses in the concrete on the unreinforced side and tensile stresses in the concrete on the reinforced side. In a concrete pavement, with the reinforcement placed near the top or bottom, there would be unequal shrinkage at these two surfaces, thereby creating a tendency to curl and crack. To eliminate the unequal shrinkage in concrete pavements, due to eccentric

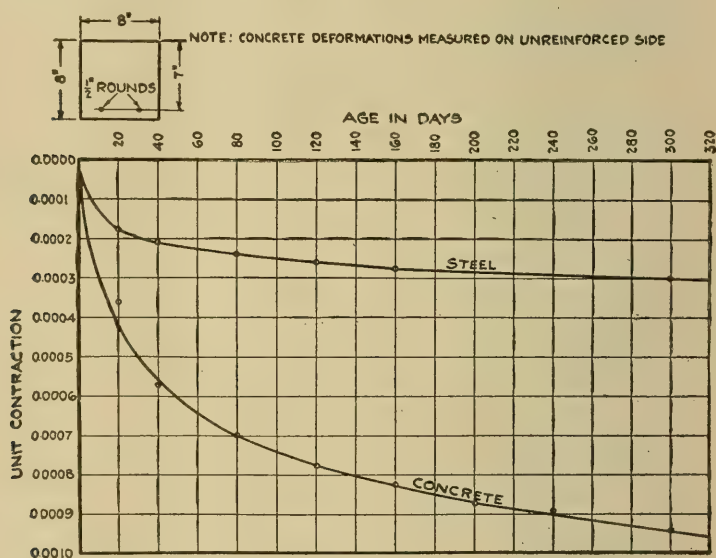


FIG. 11.—Specimen reinforced on one side.

placing of the steel, and at the same time to take care of settlement cracks as efficiently as possible, it is well to place the reinforcement in the center of the pavement.

MEASURING THE EXPANSION AND CONTRACTION OF CONCRETE ROADS.

Although the laboratory measurements of expansion and contraction of concrete gave much information on the influences affecting the length of a concrete road, the actual conditions of moisture in the road are so different from those of the laboratory that it was thought well to obtain additional information of the movements that take place by actually measuring the changes in the road.

A concrete road is subjected to a great range of variables. In the initial stages of its hardening it generally is kept moistened arti-

ficially for a period of 10 days. It is then subjected to all of the changes of temperature and moisture of the atmosphere. In addition to atmospheric influences, however, the condition of the sub-base has an effect on the condition of the concrete. If the sub-base be not well drained, there will be very little tendency for the concrete to dry, irrespective of weather conditions. On the other hand, with a well-drained sub-base the moisture may disappear rapidly after a heavy rain, and the concrete then will dry out quickly. In either case the concrete will absorb much moisture from the underlying soil by capillarity, so that the extreme drying experienced by laboratory specimens rarely will take place in the concrete road. The shrinkage changes of laboratory specimens therefore should be expected rarely in actual construction, as the conditions are not generally favorable. It is possible, however, that expansion due to the absorption of moisture will be accentuated in the concrete road.

A special instrument was designed by one of the authors in order to study the effect of temperature, moisture, and any other physical influences on the expansion and contraction of concrete roads. As the movements in the concrete undoubtedly were small, it was necessary that the measuring apparatus possess great accuracy. It also was necessary, in view of the great temperature ranges to which the instrument would be subjected throughout the day's work and at various seasons of the year, to have some means of correction for these changes in temperature. It was considered advisable, in view of the extremely small changes in length expected in the concrete, to make the measurements over quite a large gauge length, and for this reason 10 feet was selected as the length of the instrument. The device (fig. 12) in its final shape as used on the road, is made up of two gauge tubes, one of steel and one of brass, supported so that they can not bend, and provided with rounded tips against which measurements are made with micrometer screws. By means of these micrometer measurements, corrected to constant temperature, the changes in length between plugs set in the concrete road are obtained.

The tubes A and B are the gauge tubes, and they are supported at frequent intervals by brass disks, D, fastened within a brass casing, E, 2 inches in diameter. This casing extends the full length of the instrument and is surrounded and supported at intervals by another casing, F, 3 inches in diameter. At the ends of this outer casing are two collars, N, which rest in the supporting blocks, G. These blocks are provided with pins, H, whose conical ends fit into holes drilled in bronze plugs set in the road during its construction. One end supporting block, G, is provided with flat-ended contact pins, J, and the block at the other end of the instrument carries micrometer screws, I. Adjusting screws, M, shown in the end view are provided merely to support the instrument on the road, when not in use. The fiber col-

lars, L, likewise are provided merely for protection when the tube is detached from the end supporting block.

The great length of the instrument with the consequent attendant probability of the temperature at the two ends being different, due to one end being in the shade and the other in direct sunlight, led to the use of two gauge tubes of different materials from which to take measurements. Knowing the coefficients of expansion of these tubes, obtained by proper calibration, the difference in the micrometer readings furnished a means of obtaining the temperature of the bars. This temperature then could be used in correcting the micrometer measurements to a standard temperature. Thermometers were inserted in the 2-inch casing at the ends of the instrument. The mean of these end temperature readings, as a rule, approached within 1° C. of the temperature obtained from the micrometer readings.

Before using this instrument on the road it was calibrated in order to obtain the coefficients of expansion of the steel and brass tubes. In doing this a 10-foot steel gauge bar was mounted in a tank of water and immersed about 1 inch below its surface. Thermometers were laid in the water on top of the gauge bar and read from time to time

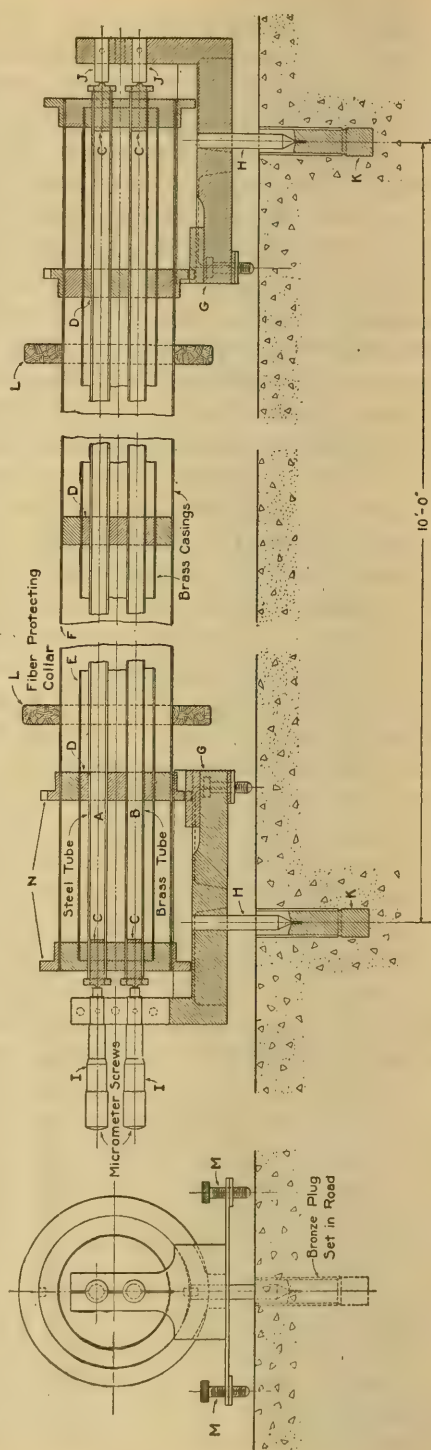


FIG. 12.—Instrument for measuring the expansion and contraction of concrete roads.

to insure that the temperature was not changing. The instrument then was mounted on the gauge bar, and a jet of steam was passed through the inner casing surrounding the steel and brass tubes. When the temperature of this inner casing had become constant, micrometer readings were taken. A stream of cold air then was run through, and again temperature readings were taken at each end of the instrument, until it was determined that the inside temperature had become constant. Micrometer readings were taken again. Several sets of readings made in this way gave values for the coefficient of expansion of the steel tube averaging 0.0000110 per degree centigrade, and for the brass tube 0.0000179. Knowing the difference in readings in the steel and brass tubes at the two measured temperatures, and having determined the coefficients of expansion of the metals, a curve giving the difference in length of the bars at various temperatures was plotted readily. When readings were made out on the road the temperature of the bars of the instrument was obtainable easily by means of the difference in their measured length.

Bronze plugs spaced 10 feet apart were set in the concrete road. A depressed cone formed the top surface, and its center was drilled with a one-sixteenth-inch drill. The top of the plug was protected with a brass tube which was set flush with the surface of the road, and, except when readings were taken, was filled with putty. Great care had to be exercised in setting the plugs as nearly 10 feet apart as possible so as not to exceed the range of the instrument. The greatest possible care likewise was taken to keep the holes in the plugs clean while measurements were being made.

In manipulating the instrument one operator was required at each end. After setting the supporting points of the blocks into the holes drilled in the plugs the brass and steel gauge bars were slid gently through the casing a very short distance, slightly jolting the blocks. This seemed to settle them into place so that check readings could be taken. After each reading the instrument was removed entirely from the holes and reseated. The readings were repeated again, and an average of three or four more was recorded as the true reading for the set. The steel-bar reading then was corrected to what it would have been if the bar had remained at constant temperature, and in this way changes in temperature of the instrument were eliminated.

RESULTS OF TEST MEASUREMENTS AT CHEVY CHASE, MD.

Beginning in September, 1912, a length of experimental road was constructed on Connecticut Avenue, beginning at Bradley Lane and extending north to Chevy Chase Lake. This road was composed of six sections of different varieties, as follows, beginning at Bradley Lane:

Section I. Bituminous concrete, Topeka specification.

Section II. Bituminous concrete, District of Columbia specification.

Section III. Cement concrete, surface treated with bituminous materials.

Section IV. Oil-cement concrete.

Section V. Cement concrete.

Section VI. Vitrified brick.

Some of the above sections were not built in continuous lengths.

Because of unfavorable weather, work was stopped on this road on December 15, after the concrete of Section III had been poured. Work was resumed in the following spring and carried to completion. On the bottom of figure 13 will be found a partial layout of the various sections of the road as constructed, giving the dates of construction and the character of the coarse aggregate. A complete description of the road and method of construction may be found in other publications of this office.¹

During the construction of the cement concrete sections bronze plugs of the type previously described were inserted in the road surface, spaced 10 feet apart in a line 5 feet from the east side of the road. At every fifth plug there was placed also a transverse plug offset 10 feet from the line of plugs paralleling the road. The layout of the sections of the road measured is shown in figure 13.

The first set of measurements was taken as soon as practicable after the concrete had hardened. The dates and temperatures are given on this plate just above the road layout. Referring to the second set of readings, it will be seen that in general, when the temperature is lower than the initial temperature, the uncracked portions of concrete show contraction, and when the temperature is higher than the initial temperature, expansion occurs. Cracks are indicated by dotted lines and are seen at various intervals throughout the length of the road, in practically all the different sections except that containing limestone aggregate. In the cold weather, during which this set of readings was taken, the cracks opened up, as shown by the expansion readings. The shrinkage of the concrete naturally would cause an opening of the cracks.

In the spring of 1913 a bituminous carpet coat was placed over the concrete up to the end of the oil-cement gravel-aggregate section (station No. 210), and expansion measurements were made in the hot weather of the spring, summer, and fall. It is interesting to note that the readings taken on July 3, 1913, all showed expansion, even those taken over the cracks. Expansion at the cracks as well as in the concrete is rather difficult to account for with certainty. However, during the previous winter the cracks undoubtedly opened up very wide during the coldest weather, owing to low temperature contraction, aided perhaps by the freezing of water in the cracks, and became filled with material from the road which prevented

¹ Office of Public Roads Circular No. 99. U. S. Department of Agriculture Bulletin No. 105.

EXPANSION AND CONTRACTION - INCHES IN 10 FEET

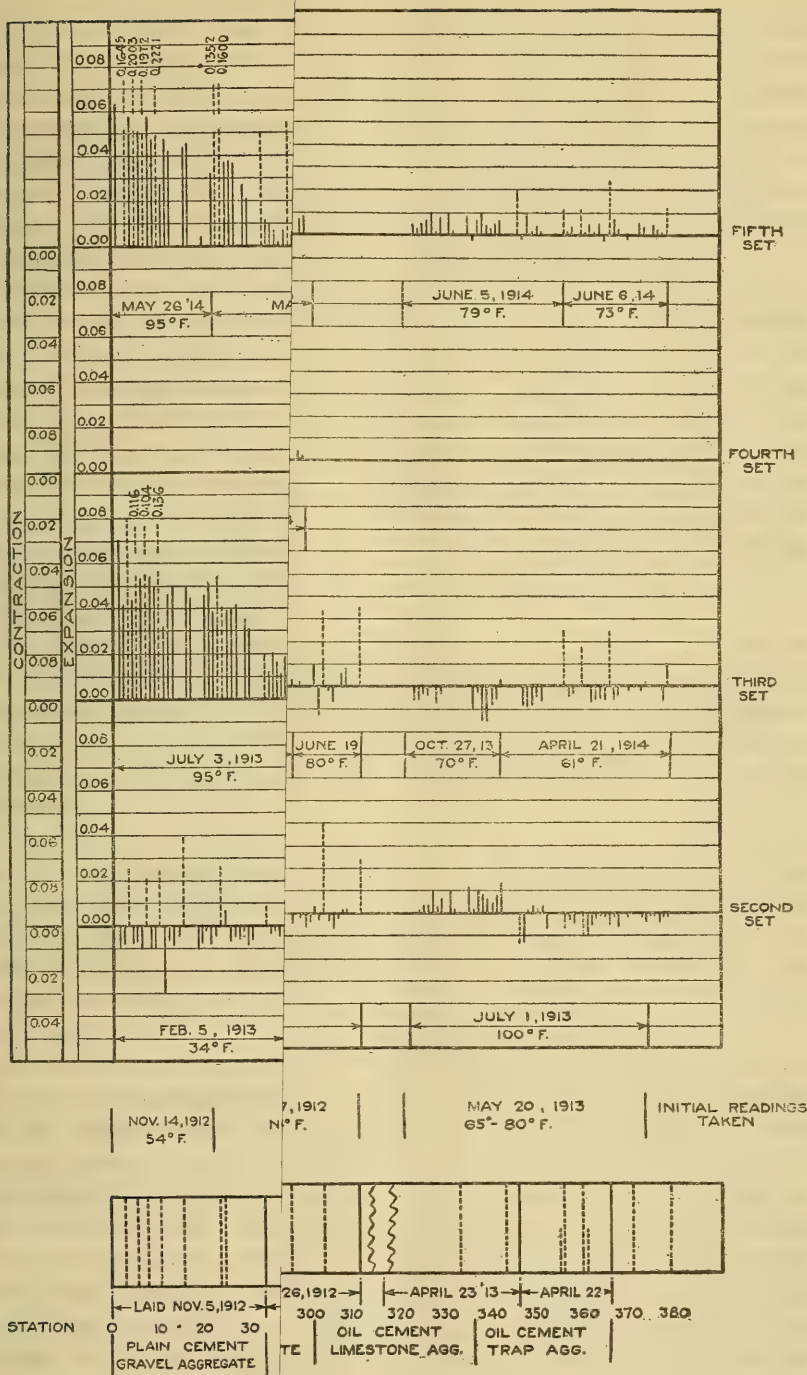
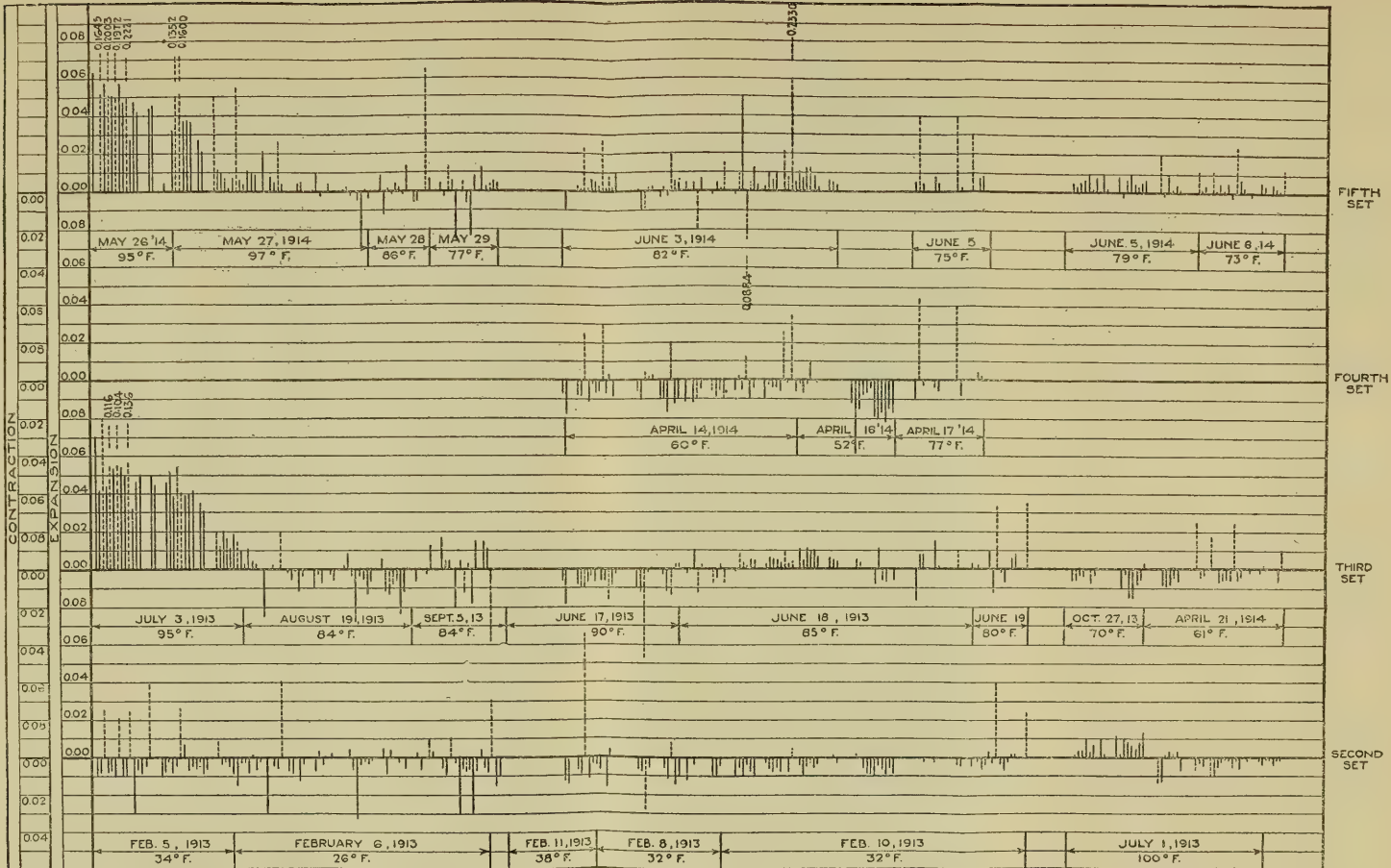


FIG. 13

Md. Laid in 1912 and 1913.



LAYOUT OF EXPERIMENTAL SECTIONS

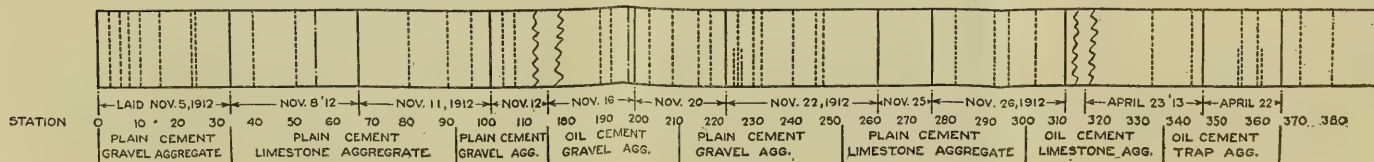


FIG. 13.—Expansion and contraction of concrete road, Connecticut Ave. extended, Chevy Chase, Md. Laid in 1912 and 1913.

them from closing when the expansion of the adjacent concrete took place. The section of road read on July 3 was adjacent to a stretch of bituminous concrete laid on a concrete base. On the very hot day preceding these readings there was an upheaval at the junction of the concrete section with the bituminous concrete section, and the concrete base of the bituminous pavement was sheared off to some extent. Note that one of the cracks had opened more than one-eighth of an inch when the readings were taken.

Measurements made on August 19 are very little different from those of the preceding February, notwithstanding the high temperature existing during the August readings. The September 5 and June 17 readings also are peculiar in that they show very little change from those of the preceding winter, and, moreover, the June 17 readings still show contraction, notwithstanding the hot weather. On June 18, with the temperature not greatly different from that of the preceding day, a slight expansion was shown. No definite conclusions can be drawn from the remaining readings of the third set. Some of the cracks which had opened in the preceding winter remained open during the summer, and others became smaller.

In April, 1914, an incomplete set of readings was taken and the concrete in general showed decided contraction compared with the preceding summer. The contraction of the concrete was accompanied by an opening of the cracks. The low temperature here seems to have played an important part in influencing the length of the concrete.

The fifth set of readings, taken in the spring and summer of 1914, on the whole shows the same characteristics as the third set. In the previous July (1913) the section of road which had buckled was cut out and filled with three double courses of vitrified paving brick with tarred joints. In the spring of 1914 buckling again took place at the same spot, and the bricks were removed and the space filled with concrete.

Note that at the fifth set of readings some of the cracks showed by actual measurement an opening of nearly one-quarter of an inch at the section where maximum expansion took place. The crack openings were even wider than during the preceding summer. Unfortunately, no measurements were made over this section during the winter of 1914. It is probable, however, that such readings would have shown that the cracks had opened very wide at this season and then were prevented from closing again because of becoming filled with loose material. It will be seen that at other sections of the road cracks which were indicated as quite small by some of the previous readings had opened wide. Note the large expansion in the crack which opened in the plain-cement gravel-aggregate section, read on

June 3, 1914, and the comparatively large contraction in the crack about 100 feet away.

Figure 15 plots the results of that part of the Chevy Chase measurements taken over the uncracked portion of the concrete. The ordinates represent the unit deformations of the solid concrete and do not include the movement at the cracks, and the abscissas represent age. At the bottom are plotted temperature and precipitation measurements for the vicinity of Washington, supplied by the Weather Bureau. The daily precipitation records were averaged for each month, and the average precipitation for the month is plotted on an exaggerated scale and is shown by the dotted line. It will be seen that there is no decided relation between the shape of the expansion and contraction curves and that of the precipitation curve. On



FIG. 14.—The measuring instrument in use on the Chevy Chase Road.

the other hand, there is a tendency for the expansion and contraction curves to conform with the temperature curve. Note that as the temperature decreases at the approach of winter the concrete contracts, and in the summer season, during the highest temperatures, the concrete expands. It would seem from this set of measurements that temperature changes have played a more important part than have atmospheric moisture changes in influencing the movements of the concrete. The moisture in the concrete may or may not bear any relation to the atmospheric moisture, but will be influenced by the degree of wetness of the sub-base. Therefore, no very great importance can be attached to the precipitation record. Note that at the beginning of the measurements, just after the concrete was laid, there was a contraction in every case, notwithstanding the fact that the temperature remained not far from constant. It would seem that this

initial contraction must be explained by the drying out of the moisture in the concrete. It has been shown in the previously described

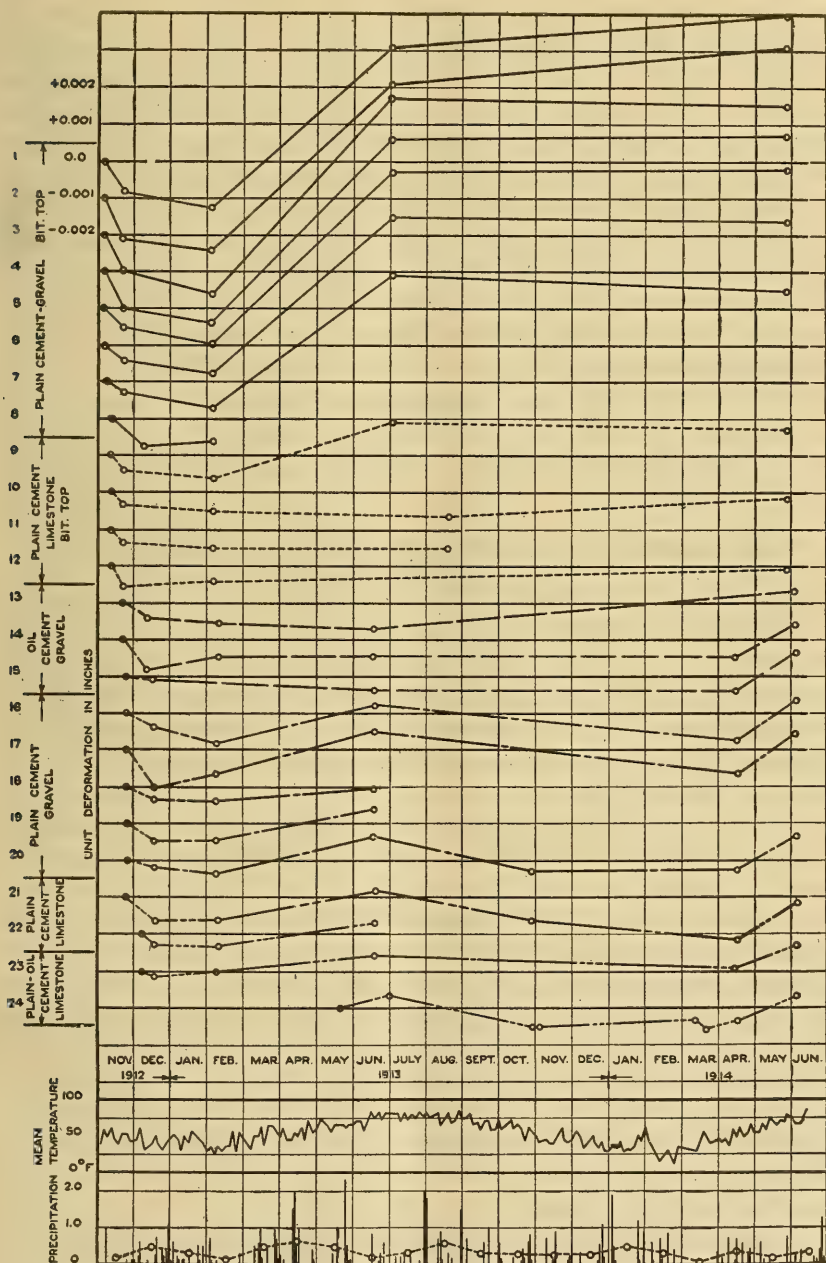


FIG. 15.—Curves of unit expansion and contraction of uncracked portions of concrete road, Chevy Chase, Md.

laboratory tests that great shrinkage of concrete can take place during the initial stages of hardening, due to the drying out of the moisture,

and it is an observable fact that as soon as the wet-earth covering is removed from the surface of the concrete it begins to dry out and, necessarily, to shrink. The maximum average shrinkage shown by the concrete in any of the sections of different mixtures was approximately 0.0001 inch per inch of length, and this occurred about three months after the pavement was laid. The temperature in this time, however, had dropped 20°, and this fall in temperature accounts almost exactly for the shrinkage. It has been shown by means of laboratory specimens stored out of doors and subjected to all the changes of the atmosphere that very little change in length takes place under such conditions. It seems probable that the moisture content of the concrete at Chevy Chase changed so little that the length of the concrete was very little affected thereby. A hard rain, thoroughly soaking the concrete, will have no immediate great effect upon its length. It has been pointed out that moisture changes are rather slow and progressive, and therefore it is unlikely that hard rains of even several days' duration will have great effect on the expansion of the concrete in the road.

EXPANSION AND CONTRACTION OF OHIO POST ROAD.¹

These measurements were taken over three 300-foot experimental sections of the concrete Ohio Post Road constructed in 1914 under the supervision of the Office of Public Roads. The Ohio Post Road is located partly in Muskingum County and partly in Licking County, Ohio, and runs west from Zanesville, Ohio, for 24 miles over the old National Pike to the Moscow Bridge over the South Fork of the Licking River. This road was constructed on a sub-base composed mainly of a stiff red clay. The total width of concrete surfacing is 16 feet, with a thickness of 6 inches at the edges and 8 inches at the center. Expansion joints made of one thickness of 2-ply tar paper were spaced 30 feet apart throughout the length of the road, with the exception of the three experimental sections, on each of which the spacing varied from 20 feet to 100 feet, intervening sections being 40, 60, and 80 feet long. Expansion joints were placed at an angle of 15° across the road. Both gravel and crushed stone were used as coarse aggregate, the proportions in the former case being 1:1½:3 and in the latter 1:1¾:3. Crushed stone used in the experimental sections was obtained from limestone quarried on the Scioto River at Marble Cliff. The sand and gravel were obtained from a washing plant at Dresden, Ohio.

As soon after laying as possible the concrete surface was covered with canvas, which was removed when the concrete was 24 hours old and replaced by a 2-inch earth covering. This was allowed to remain

¹ The authors desire to acknowledge the assistance of the Ohio State Highway Department in conducting the tests on this road.

on the road for two weeks and was kept wet. At the end of that time it was removed and the road opened.

LOCATION OF EXPERIMENTAL SECTIONS.

The three 300-foot experimental sections referred to above were located on the road as follows:

Section I, in Licking County, one-half mile east of National Road Station. This section comprised the last 300 feet at the bottom of a 4 per cent grade 2,000 feet long. The coarse aggregate was limestone, and the section was laid July 6, 1914. The distances between expansion joints varied from 100 to 20 feet, as noted above, with the 100-foot section at the bottom of the grade. At the time of laying bronze plugs, similar to those used in the Chevy Chase experiments, were cast 10 feet apart along the center of the road. Readings on this section were taken on July 7, 8, and 22, on October 31, 1914, on March 4 and June 19, 1915, and on February 25, 1916.

Section II, in Licking County, about 500 feet east of Moscow Bridge, on a 0.4 per cent grade. Limestone was used as the coarse aggregate, and the spacing of the joints and placing of the measuring plugs was the same as on Section I. The first 180 feet of this section was laid on July 29 and the last 120 feet on July 30. This break was caused by an accident to the mixer. Readings were taken on August 1, November 2, 1914, on March 3 and June 17, 1915, and on February 25, 1916.

Section III, in Muskingum County, at Mount Sterling. This section was laid at the bottom of a vertical curve with a 6 per cent grade 400 feet long rising eastward and a 6 per cent grade 600 feet long rising westward. Gravel was used as a coarse aggregate. The section was laid on November 5, 1914, and readings were taken November 6 and 7, 1914, March 6 and June 15, 1915, and February 22, 1916.

MEASUREMENTS ON SECTION I.

The initial readings on Section I were taken on July 7, 1914, one day after the concrete was laid. The temperature of the concrete was determined by means of a thermometer inserted in a small brass tube cast in the top of the pavement, the thermometer bulb being about 4 inches below the surface of the pavement. The hole was packed with putty and covered with a box to protect it from the sun, and here the thermometer was allowed to remain until a uniform temperature was obtained. On July 8, one day after making the initial readings, or two days after the concrete was laid, the second set of readings was taken and is shown graphically on the curve. If a crack is included within the 10-foot gage length, the reading is indicated by a dotted line; if a construction joint is included it is shown by a dash and dot line. Almost all the readings taken over

the solid concrete show a slight contraction, while the joints show an expansion, or, in other words, they have opened slightly. The contraction of the concrete took place notwithstanding the fact that it was wet continually. It is to be noted, however, that the temperature fell from 82° on July 7 to 75° on July 8, and this probably accounts for the slight contraction observed.

Up to July 22 the road was kept covered with wet clay, and the third set of readings was taken on this date. Here it is noticed that there is a slight expansion of the concrete with a large contraction at three of the joints and an expansion at two. The temperature at these readings was slightly higher than that taken during the initial readings. This, combined with the moisture expansion, could account

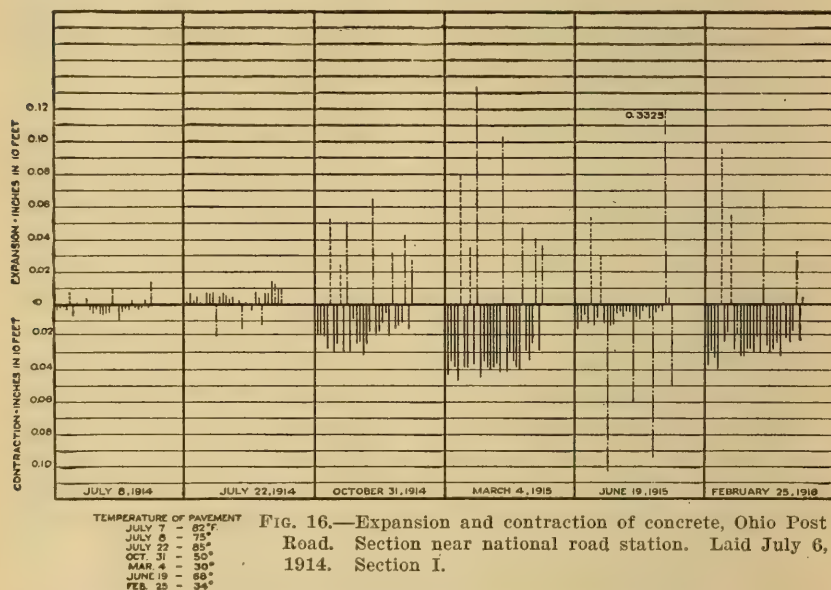


FIG. 16.—Expansion and contraction of concrete, Ohio Post Road. Section near national road station. Laid July 6, 1914. Section I.

for the slight expansion noted in the concrete. But during this period of initial hardening, while the concrete was kept wet, it is seen that very little change took place in its length. It is important to note, however, that even on the second day, when the readings showed a slight contraction of the concrete, a transverse crack appeared. The slight tensile stress induced in the weak green concrete by the contraction evidently was enough to produce rupture.

Just after July 22 the earth covering was removed from the road surface, and it was subjected directly to atmospheric influences. On October 31, with the pavement temperature at 50° (32° lower than the initial temperature), the uncracked concrete showed large contraction, while the cracks and joints opened or gave an expansion

reading on the instrument. The total contraction over the uncracked portions of the pavement equaled 0.462 inch in a total length of 230 feet, or 0.00017 inch per inch of length. The calculated contraction for the fall in temperature between the initial reading (82°) and this reading (50°) equals 0.000176 inch per inch of length, almost identical with the actual measured contraction.

On March 4, when the temperature of the pavement was 30° F., another set of readings was taken. In the interval the pavement had been subjected to the extreme cold of the winter. Here again is seen the effect of change in temperature upon the concrete. That part of it which remained free from cracks contracted 0.000307 inch per inch of length. The decrease in temperature during this period was 52° , and hence the theoretical contraction would be equal to 0.00029 inch per inch of length, so that here again the temperature influence seems to be borne out by actual measurement. It will be seen that the cracks and expansion joints in this section opened considerably, and the colder the weather the greater the openings became.

In June, 1915, not quite a year after the road was constructed, another set of readings was made and gave the results shown on the curve. The warm weather had decreased the contraction of the concrete below the amount shown in the preceding March. This section was laid in warm weather when the temperature exceeded 82° and the temperature for the pavement on June 19 was only 68° , so that some contraction of the uncracked concrete should be expected. This amounted to 0.0167 inch, or 0.00006 inch per inch of length. The theoretical contraction for this fall in temperature is 0.000077 inch, just a little more than the actual measured contraction. A feature of this measurement is the great contraction at some of the expansion joints and a very large expansion at another joint and at two of the cracks. The large contraction or closing of some of the joints and the large opening at one may be accounted for by the relative movements of the slabs due to inequalities in the sub-base and to the fact that the section under test is at the bottom of a long 4 per cent grade.

In February, 1916, the last set of measurements was taken in cold weather. Here again the contracting effect of low temperatures is seen on that part of the concrete which has remained intact. A contraction of 0.00023 inch per inch of length occurred by actual measurement, whereas the figured temperature contraction was 0.000264 inch per inch of length. Temperature again has played a prominent part in influencing the length of the concrete. Note that the 100-foot length cracked in two places, whereas the sections of smaller length did not crack.

MEASUREMENTS ON SECTION II.

OHIO POST ROAD AT MOSCOW BRIDGE.

Section II was laid on a 0.4 per cent grade with limestone aggregate with joints spaced successively 20, 40, 60, 80, and 100 feet apart. This section, laid one month later than Section I, showed much the same characteristics as far as expansion and contraction are concerned. As the weather became colder and colder, the concrete showed more and more contraction. In the hot weather of the summer one year after laying the concrete showed about the same amount of expansion that it showed three days after laying. One of the cracks, however, that had opened in the preceding winter, instead of closing because of the expansion of the concrete, remained open, probably

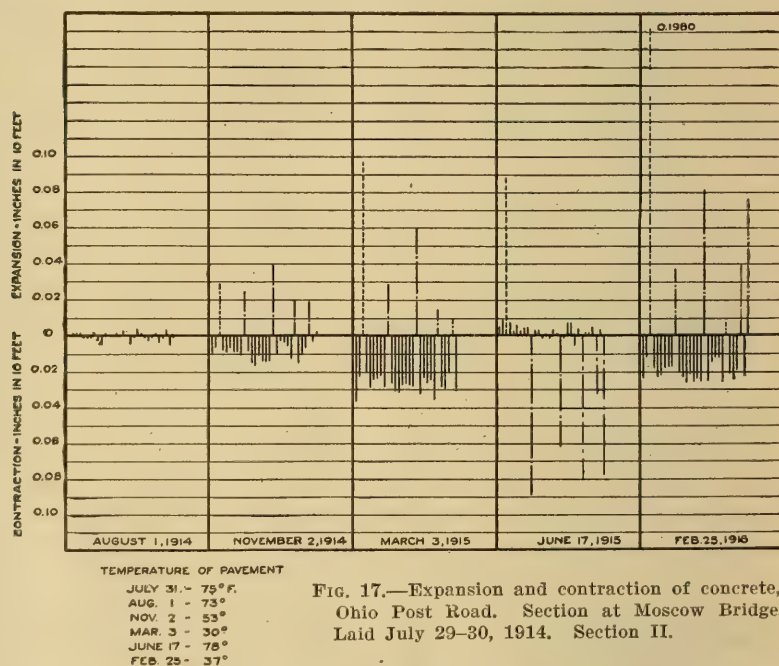


FIG. 17.—Expansion and contraction of concrete, Ohio Post Road. Section at Moscow Bridge. Laid July 29–30, 1914. Section II.

owing to the presence of foreign material. This same crack opened considerably wider in the cold weather of the following winter, as seen in the measurements of February 25, and the remaining joints likewise expanded considerably. Note that a crack formed in the 100-foot section and did not form in the 20, 40, 60, or 80-foot sections.

MEASUREMENTS ON SECTION III.

OHIO POST ROAD AT MOUNT STERLING.

Section III shows much the same characteristics as the preceding Sections I and II. This section was laid on November 5, and the initial readings were taken on November 6 at a temperature of 51° F.

On November 7 the second set of readings was taken at a temperature of 54° F. A very small expansion of the concrete was indicated, but at one of the joints a small expansion took place. This is somewhat hard to explain but is of no practical consequence, since it is so small. On March 6 the third set of measurements was taken when the temperature was 37° F., or 14° lower than the initial temperature. Note the large contraction of the concrete and the correspondingly large expansion at the joints and at the single crack that formed in the 100-foot section.

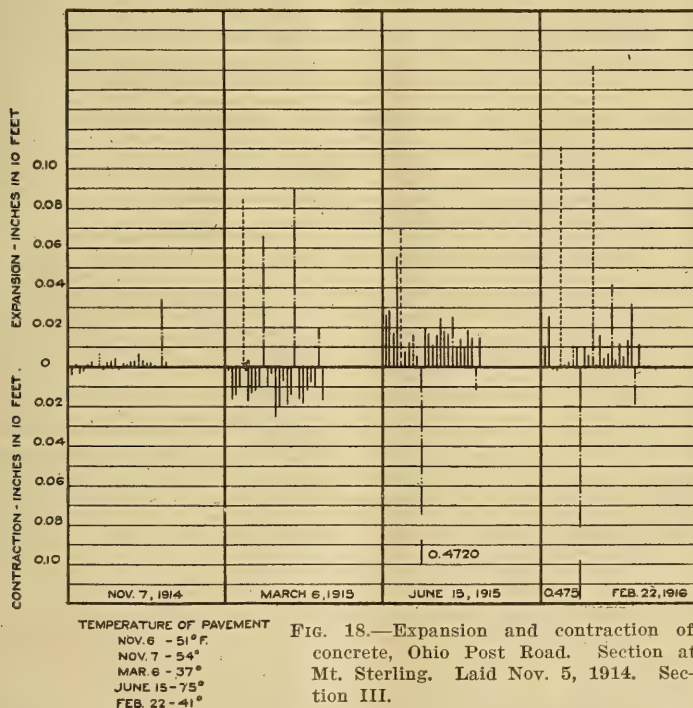


FIG. 18.—Expansion and contraction of concrete, Ohio Post Road. Section at Mt. Sterling. Laid Nov. 5, 1914. Section III.

On June 15 the fourth set of readings was taken at a temperature of 75° or 24° warmer than when the initial readings were made. Again it will be noticed that the uncracked portions of the concrete have expanded with the higher temperature. A second crack had formed during the previous winter, and it, together with the first formed crack, showed expansion or widening. Note the enormous contraction of one of the expansion joints, a contraction of 0.472 or almost one-half inch. One side of this joint overrode the other, so that it projected above the surface of the road about $1\frac{1}{2}$ inches. The last set of readings was taken on February 22, when the temperature was 10° F. below the initial temperature of the road. Enormous expansions are seen to have occurred at the cracks and smaller expan-

sions at some of the expansion joints, and the joint which had pushed together and overrode during the preceding summer remained in the same condition.

In an effort to determine whether atmospheric moisture or temperature played the most important part in influencing the expansion

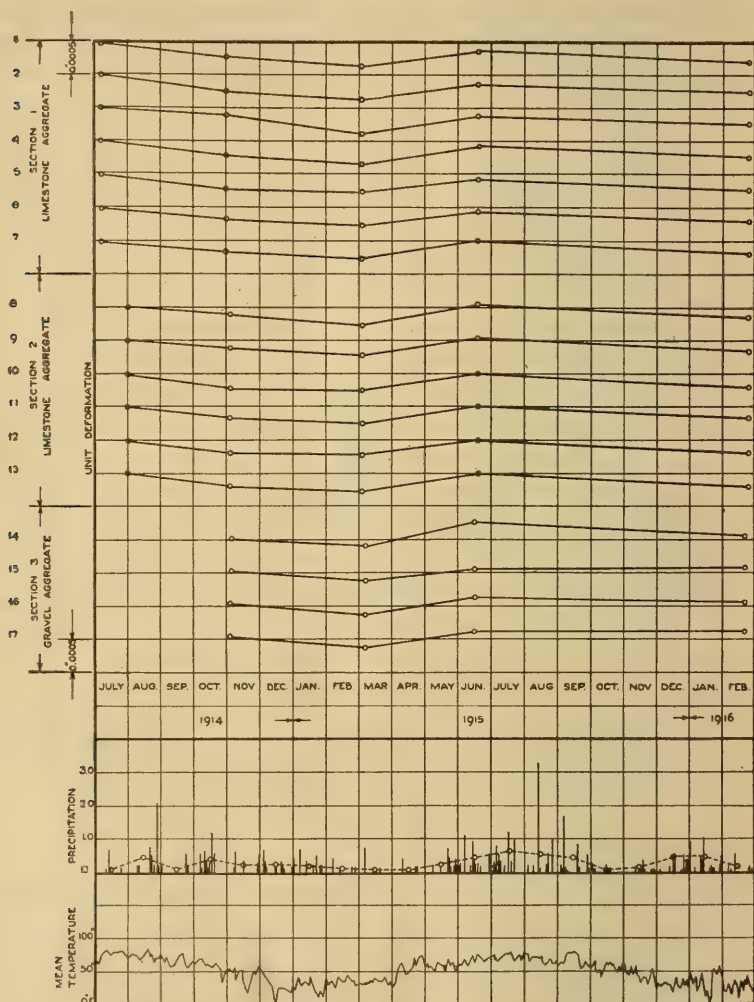


FIG 19.—Curves of unit of expansion and contraction of unracked portions of concrete road, Ohio Post Road.

and contraction of the Ohio road, the curves shown in figure 19 were plotted. The unit expansions and contractions shown were obtained by summing up the changes in the concrete in the unracked portions. Each curve represents the unit deformation in a different slab of concrete included between different joints or cracks. In the same section of road these curves should be of practically the same

shape, since the kind of concrete and temperature and other conditions were identical. The precipitation records were obtained from the Weather Bureau records for Columbus, Ohio, and are approximately correct for the three different sections of road measured. The precipitation records during each month were averaged, and the dotted curve represents this average. It is difficult to distinguish the effect of temperature from that of moisture, as indicated by the precipitation curve, since they are so nearly identical. Again, it must be pointed out that the condition of moisture in the concrete is dependent on the moisture in the sub-base rather than on atmosphere moisture, and the precipitation curve is only a general indication of the moisture in the sub-base.

GENERAL DISCUSSION OF THE EXPANSION AND CONTRACTION OF CONCRETE PAVEMENTS.

The preceding laboratory and field measurements show that concrete changes in length owing to at least two separate agencies: (1) Change in moisture content and (2) change in temperature.

(1) *Change in moisture content.*—By laboratory measurements made on large specimens it has been demonstrated that concrete changes in length from its wet condition just after setting to an extremely dry condition at six months or one year later by an amount equal to 0.0005 to 0.0006 inch per inch of length. A change of 0.0006 inch is as much as would be caused by a change in temperature of $0.06 \div 0.000055 = 109^\circ$ F. and would produce considerable stress under favorable conditions. This change, however, is a very slow one. It occurs most rapidly during the first few weeks of drying out and becomes very slow at the end of three months. At one year the change due to drying will have become constant in amount. It has also been seen that when concrete is kept wet it does not contract, but it expands and maintains a constant expansion of about 0.0001 inch per inch of length. Furthermore, it has been demonstrated that by subjecting hardened concrete to alternate wetting and drying, its length may be changed irrespective of temperature changes. Such moisture changes, however, are rather slow in their action and a prolonged period of wet conditions or a prolonged period of dryness is necessary to effect a large change in the length of the concrete such as might be obtained in a very short time by the influence of temperature. When specimens are stored in the weather and subjected to rain and sunshine, they change very little in length because of moisture changes, unlike specimens that are stored under prolonged conditions of extreme wetness or dryness.

In the field measurements on the Chevy Chase and Ohio Post roads, except that at Mount Sterling, Section III, it is difficult to distinguish the effects of moisture, since apparently they are overshadowed so

greatly by the temperature expansion and contraction. It seems that the concrete in the road, when subjected to actual weather conditions, does not suffer the prolonged extreme ranges of moisture content suffered by the laboratory concrete specimens kept indoors in the dry air of the laboratory and therefore does not expand or contract because of moisture changes to the extent that the laboratory specimens change. Undoubtedly in warm, dry weather there will be some slight contraction just after the moisture is allowed to dry out from the concrete, particularly in a well-drained sub-base. It seems that enough of the water absorbed by the concrete, due to rains or to capillarity, remains in the concrete during the dry weather to prevent much change in length. There may be conditions of prolonged extremes of wetness and dryness in the road which will affect the expansion and contraction to an appreciable extent. Thus in the spring of the year the prolonged moisture of the previous winter might so aid the expansion occurring during the first day of high temperature that the road will heave where proper allowance has not been made for this expansion. There are also conditions of poor drainage in the sub-base, particularly in a low section in the road, where the concrete will be practically constantly saturated, in which case the expanding effect of the moisture will be in evidence.

(2) *Effect of variations in temperature—field measurements.*—It has been pointed out that, as a rule, the concrete in a road expands and contracts as the temperature rises and falls. It will be interesting to compare the actual measurements of the expansion and contraction of the concrete in the road with the calculated change, assuming no friction at the base and assuming a coefficient of expansion of 0.0000055 per degree F. Table I shows a comparison of the actual with the theoretical unit changes in the concrete of the Ohio Post Road.

TABLE I.—*Change in length of concrete in Ohio Post Road.*

	Section I.				Section II.	
	Oct. 31.	Mar. 4.	June 19.	Feb. 25.	Nov. 2.	Mar. 3.
Change in temperature.....	—32	—52	—14	—48	—22	—45
Actual unit change.....	—0.00017	—0.00031	—0.000064	—0.00023	—0.000076	—0.000227
Calculated temperature change	—0.000176	—0.00029	—0.000077	—0.00026	—0.000121	—0.000248

	Section II.		Section III.			
	June 17.	Feb. 25.	Nov. 7.	Mar. 6.	June 15.	Feb. 22.
Change in temperature.....	+3	—38	+3	—14	+24	—10
Actual unit change.....	+0.000024	—0.000168	+0.0000096	—0.000109	+0.000148	+0.000072
Calculated temperature change	+0.000017	—0.00021	+0.0000165	—0.000077	+0.000132	—0.000055

These comparisons of the actual change with the theoretical change, considering temperature alone to be the cause, are interesting. Observe that in Section I the agreement of the theoretical with the actual change in length is quite close, indicating that temperature was almost the sole cause of the change, and indicating, moreover, that the resisting effect of friction at the base must have been small. In Section II the agreement is not quite so close, and in Section III the agreement is poor. The actual unit change in many cases is in excess of the calculated temperature change, thus indicating that moisture is causing some expansion and also that the restraining effect of friction in preventing expansion and contraction may be quite small.

The discrepancies between the measured changes and theoretical changes are very noticeable in Section III. It will be seen from the description of Section III that it lies at the bottom of two 6 per cent grades and the conditions are very favorable for a wet sub-base. Moreover, this section of the road was covered continually with mud tracked in from adjacent roads, and this aided in preserving the road in a moist condition. The actual change in length on June 15 and February 22 was greater than the calculated change, and these days were preceded by a considerable period of wet weather, as shown by the precipitation curve. These conditions were promotive of a wet sub-base, and this probably accounts for the increase in expansion of the actual over the theoretical. On June 15 the actual expansion is 0.000148 minus 0.000132, or, 0.000016. On February 22 the excess unit expansion equals 0.000127 inch. As shown by laboratory measurements, this is approximately the amount of expansion produced in concrete by continued moisture, and this measurement therefore tends to confirm the presumption that the moisture effect is causing the difference between the actual expansion and calculated temperature expansion. The apparently small effect of friction in preventing expansion is interesting and is not unreasonable when it is considered that the pavement is subjected to continued vibration which would tend to relieve temporarily any friction between a wet clay sub-base and the concrete. Moreover, the slow yielding of the sub-base as the concrete creeps helps to relieve the stresses of friction.

The foregoing expansion and contraction measurements are presented in the hope that they will be of assistance to the engineer having charge of concrete road construction. Much theory might be developed from these measurements, but this development, together with the practical application of the results, will be left for the present to the constructing engineer. Some broad conclusions may be stated as the result of the investigations described, combined with the investigations of others.

CONCLUSIONS, BASED ON EXPANSION AND CONTRACTION MEASUREMENTS.

1. Neat cement when allowed to dry, first contracts rapidly, then more slowly. The amount of contraction seems to vary with the cement, size of specimen, and condition of atmosphere in which drying takes place. The amount at 28 days is about 0.1 per cent and at 6 months about 0.2 per cent.

2. Mortar contracts on hardening in air and expands on hardening in water. The contraction in warm, dry air at 28 days is about 0.045 per cent for 1:2 and 1:3 mortar and at 6 months is 0.078 for 1:3 mortar and 0.085 for 1:2 mortar. The expansion in water is 0.01 per cent for 1:3 and 0.017 for 1:2 mortar at 28 days, and at 6 months 0.013 for 1:3 and 0.02 per cent for 1:2 mortar.

3. Both 1:2:4 and 1:3:6 concrete contract on drying in warm, dry air from 0.02 to 0.04 per cent at 28 days and from 0.04 to 0.07 per cent at 6 months. When hardening in water an expansion of about 0.01 per cent takes place at 28 days and 6 months in 1:2:4 and 1:3:6 concrete.

4. The richness of the mix of concrete seems to exert a small influence on the contraction; the richer the mix the greater the change in length.

5. Concrete alternately wetted and dried may be made to expand and contract owing to these causes. The expansion due to wetting is more rapid than the contraction on drying. The thoroughly dried specimens of concrete do not recover their original wet length when immersed.

6. Concrete stored in the outer air and exposed to the weather does not contract to the same extent as the above described specimens except under very dry conditions.

7. A waterproof covering, such as coal tar, prevents the rapid change in moisture content and greatly retards the expansion and contraction.

8. Reinforcement decreases, but does not prevent, the shrinkage and expansion of concrete due to drying and has no effect on temperature changes. Reinforcement can not, therefore, entirely prevent cracks, but seems to distribute them and keep them small.

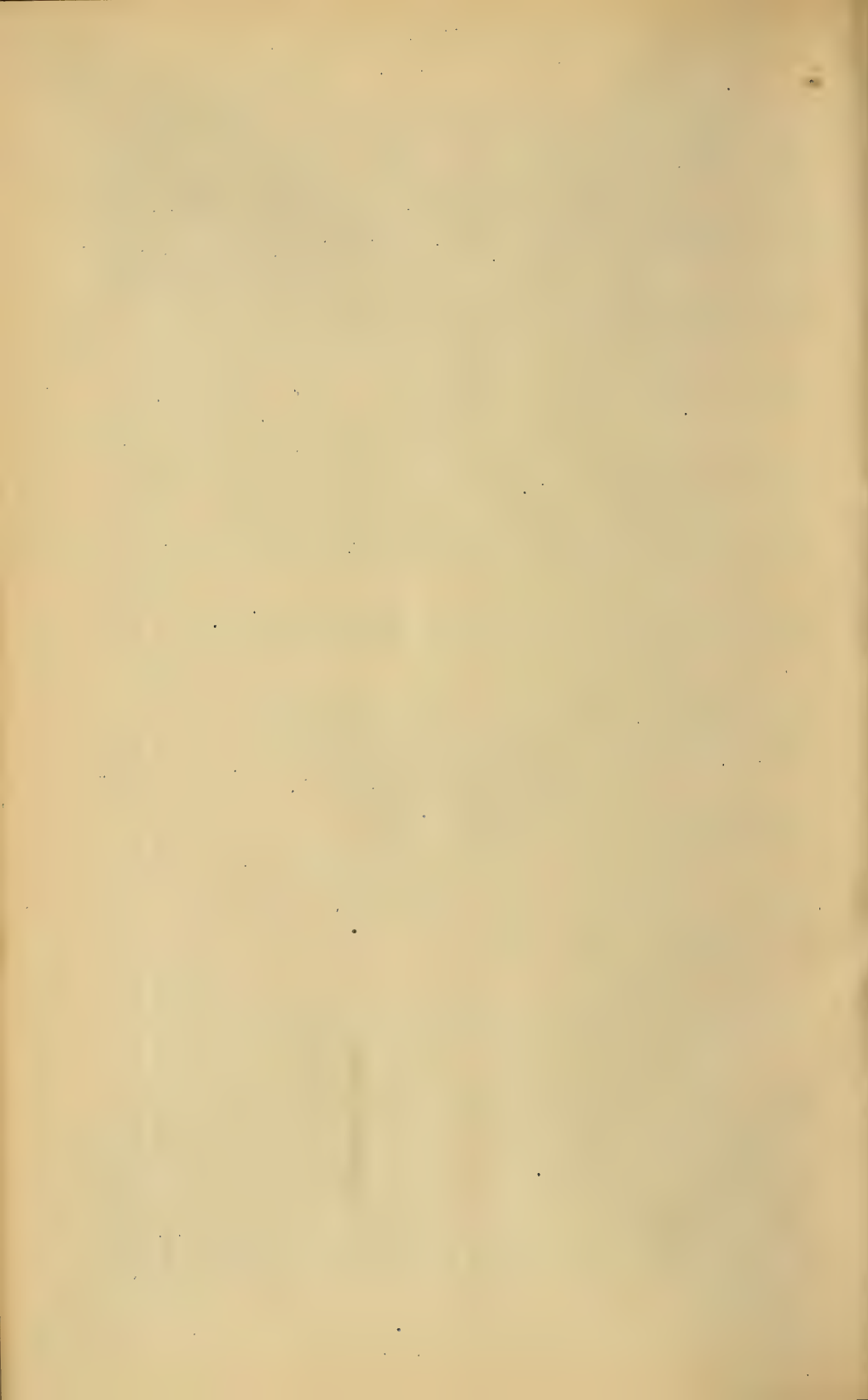
9. Concrete roads are affected by both temperature and moisture. When the drainage is good and the sub-base not wet, the temperature effects seem to be most important. A wet sub-base may add to the temperature expansion by about 0.01 to 0.02 per cent. The restraining effect of friction at the base seems to be almost negligible when figuring temperature and moisture expansion and contraction. In very dry climates shrinkage due to drying must be added to contrac-

tion due to fall in temperature. A shrinkage of 0.04 per cent (one-quarter inch in 50 feet) is a safe allowance due to drying.

10. Temperature at time of construction of road should be considered in designing joints. Cold-weather construction requires a full allowance for temperature expansion and, on wet sub-bases, for moisture expansion also. Hot-weather construction theoretically requires no joints at all, even in wet sub-bases, as the temperature contraction exceeds the moisture expansion. However, the difficulty of keeping the cracks clear probably renders joints imperative.

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UNITED STATES DEPARTMENT OF AGRICULTURE



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Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.



March 3, 1917

EXTENSION OF COTTON PRODUCTION IN CALIFORNIA.

By O. F. COOK, *Bionomist, Bureau of Plant Industry.*

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INTRODUCTION.

Every season of scarcity and high prices brings renewed inquiries regarding the possibility of extending the production of cotton into new regions. The industrial uses of cotton are being increased more rapidly than facilities of production. As Europe produces scarcely any cotton, the industries of many countries are dependent upon imported raw materials. Manufacturers continually urge the need of developing more adequate and regular supplies, especially of the better classes of cotton fiber.

Experience of the frequent fluctuations of crops and prices in the American cotton belt have led to numerous attempts, subsidized by associations of manufacturers or with the direct support of governments, to increase the production of cotton in other parts of the world. Statistics show a decline in the proportion of the world's cotton crop furnished by the United States. This means that the world's demand for cotton has grown faster than the ability of this country to supply it, and that the production of cotton in other countries is increasing more rapidly than here.

Some parts of the American cotton belt have been too acutely dependent on this single crop. Many farmers who relied entirely upon

cotton were brought to disaster through the destruction of cotton by the boll weevil or by the loss of a market at the beginning of the European war. These crises were the more acute because cotton had been considered so long a safe crop and afforded new demonstrations of the danger of complete reliance of any community on a single crop. In California it is beginning to be understood that many communities are devoted too exclusively to special industries and that there is need of some such crop as cotton for opening the way toward a safer policy of more diversified farming.

In many of the tropical and subtropical regions of Asia, Africa, and America, efforts are being made to establish cotton culture as colonial enterprises on a basis of permanent competition with the United States. There can hardly be a question of the desirability of utilizing our resources of production as far as feasible. One of these undeveloped resources is the production of Egyptian cotton, which experiments have shown to be possible in Arizona and California. The need of supplementing our importations of Egyptian cotton by domestic production has recently been very acute, and the high prices that are now being paid are attracting public attention to the possibilities of cotton growing in California.

INCREASING DEMANDS FOR LONG-STAPLE COTTON.

No danger of direct competition with the older centers of cotton production in the Southeastern States is involved in the development of cotton culture in California, for the reason that it will be so obviously to the advantage of California to produce cotton that will not need to enter into competition with the South, such as the Egyptian cotton, which our manufacturers are importing on a scale of many millions of dollars every year. All previous records were exceeded in 1916, with importations amounting to about 350,000 bales, valued at more than \$35,000,000.

The rapidly increasing demand for Egyptian and other superior types of cotton is due to a variety of causes, the most important being, undoubtedly, the enormous proportions attained by the automobile tire-fabric industry and the greater attention being given by manufacturers, dealers, and the public generally to the fact that strength and durability of fabrics depend very largely on the quality of the cotton fiber. Recognition of this fundamental fact in relation to automobile tires in time may be reflected in other branches of the textile industry and in turn lead eventually to a general elimination of the enormous waste of industrial effort involved in the production, manufacture, and use of weak, inferior fiber.

New communities can secure a great advantage in the production of long-staple cotton by limiting themselves to the planting of a single superior variety. In the older parts of the cotton belt, where

each farmer is likely to plant a different kind of cotton, the varieties can not be kept pure. The fiber deteriorates in quality and declines in market value. New varieties are introduced frequently, but these soon deteriorate through admixture and the neglect of selection. No general or permanent improvement can be expected as long as the condition of unorganized communities and miscellaneous planting continues.

NEW TYPES OF COTTON AVAILABLE.

As a result of experiments conducted by the Department of Agriculture for several years past in the Southwestern States, the Egyptian type of cotton has been acclimatized and superior varieties have been bred, which are now being raised on a commercial scale in the Salt River Valley of Arizona. During the same period numerous experiments have shown that the Egyptian cotton is not well adapted to replace the Upland type of cotton, either in Texas or farther east. Susceptibility to injury by drought and disease both appear much greater under conditions in the cotton belt. The need of a longer growing season is another serious handicap for the Egyptian type of cotton in the eastern United States and would exclude it from competition with Upland cotton in all of the regions that are infested by the boll weevil.¹

Even with the same long-staple variety grown in California as in the eastern districts, there may be no direct or injurious competition. The conditions of soil, climate, and water supply in California are so different as to give the lint distinctive qualities, and there is less danger of the annual fluctuations in yield and quality of fiber that have made it unsafe for manufacturers to rely upon eastern long staples exclusively. The production of Durango cotton in the Imperial Valley, by giving it a recognized place in the market, has served to stimulate the planting of this variety in eastern districts. This relation would doubtless continue even if the production of Durango cotton in California were greatly increased, for there seems likely to be a very large demand for this type of cotton if only it can be produced with such regularity that manufacturers can rely upon adequate supplies being available. The possibility that production might be increased more rapidly than the demand must be recognized, but it does not appear to be a present danger in view of the special scarcity and high prices of the Egyptian cotton.

As eastern varieties of cotton have not proved to be well adapted to conditions in the irrigated districts of the Southwestern States,

¹ Thus, there are natural limitations to competition in either direction. The Egyptian type is sure to be preferred in the Southwestern States as long as higher prices make its cultivation more profitable. If other types are grown they are likely to be of the same general commercial character as the Egyptian, with fiber of special qualities that can not be produced to the same advantage in the Southeastern States.

there is as little occasion for farmers to undertake to bring in Upland seed from the cotton belt as to get Egyptian seed from Egypt. To make importations of Egyptian or other foreign seed is contrary to regulations under the Federal plant-quarantine law and the State quarantine law of California and is extremely dangerous on account of the possibility of introducing the boll weevil or other parasites. The ravages of the pink bollworm in Egypt, India, and other regions show that it is a very serious pest, like the boll weevil. It is of the utmost importance to keep these insects out if cotton growing is to develop in California. While regular importations of seed are prevented, the public needs to be warned of the danger from seed that may be brought in casually by travelers or immigrants from foreign countries or by settlers from Texas or other weevil-infested States.

COTTON FORMERLY GROWN IN CALIFORNIA.

In the San Joaquin Valley, cotton growing can hardly be considered as a new industry but rather as a return to a beginning that was made in the early years of the agricultural history of the State, in the middle of the last century, and maintained through the period of the Civil War and beyond. The Ninth Census, that for 1870, notes the production of 34 bales of cotton in San Diego County, but it is known that larger acreages of cotton were being planted in the San Joaquin Valley during this period.

In the report of the Tenth Census, that for 1880, published in 1884, California was included with the other cotton-growing States on a basis of production of 295 bales, grown on 375 acres in Merced County, the lack of more complete statistics being explained by a note saying that "the enumeration schedules sent to this State did not include cotton."

In the general discussion of the conditions and prospects of cotton culture in California, also published in the Tenth Census report, plantings estimated at 1,500 to 2,000 acres are said to have been made in Merced County in 1873, and in that year a firm of Merced County growers made an export shipment of 22,886 pounds of cotton to Liverpool. This seems to have marked the climax of the early efforts, but areas of 350 to 500 acres continued to be planted in the next decade, or possibly later, though no cotton was returned from California in the Eleventh Census, that for 1890.

Hilgard shows that cotton had begun to attract attention in California as far back as 1856, when a premium of \$75 was offered by the State Agricultural Society for the best acre of cotton. In 1862 the State Legislature offered an aggregate of \$6,500 in premiums for cotton in lots of 100 bales, the best lot to be rewarded with \$3,000, but the prizes remained unclaimed until 1865, when the \$3,000 was paid to a farmer in Los Angeles County who raised 108 acres, the yield

not being stated. The counties from which successful plantings were reported in the early period are Butte, Colusa, Fresno, Kern, Lake, Los Angeles, Merced, Sacramento, San Diego, Santa Barbara, Shasta, Sutter, Tulare, and Yolo. Other counties supposed to afford conditions favorable for cotton were Napa, Sonoma, and Tehama. The general conclusions reached by Hilgard from his detailed investigations of the California cotton industry in 1879 were stated as follows:

From the record above given it appears that cotton has been successfully grown at many points, practically covering the whole of the great valley, a part of the foothill lands of Shasta and a part of Napa County, and to the southward all the agricultural portion of the southern region. By inference drawn from similarity of climate and products, without direct test, we may include within the possible cotton-growing portions of the State the valleys of Napa and Sonoma, the agricultural portion of Lake County, the foothill region of Tehama, and the entire lower foothills of the Sierra. On the other hand, all the bay region, as well as the seaward valleys of the entire Coast Range, are excluded from the cotton-growing area by reason of the cool summers, trade winds, and fogs to which they are subject.

In addition it may be broadly stated that in the Sacramento Valley cotton may on deep soils be grown without irrigation, while in the San Joaquin Valley it, like all other crops, must be irrigated to insure profitable returns. The best experience seems, moreover, to indicate that, as in the case of the vine, the minimum irrigation that will enable the plant to develop is that which on the whole gives the best results, inasmuch as late irrigation especially tends to retard the opening of the bolls and in the low portions of the fields to start new growth, leaving the older bolls stationary.

The Sea Island variety is a failure thus far wherever tried. That cotton culture has not assumed larger proportions in California as yet is adequately explained by the fact that the home market is, in the absence of cotton factories, extremely limited, and the long distance from the world's markets renders competition with the Atlantic Cotton States on the one hand and with India on the other a doubtful matter, which could be turned in favor of California only by exceptional circumstances, such as peculiar excellence of the staple. At the same time, cotton production has been found profitable so far as the home demand has gone, and good prices have been obtained; and when exported the California staple has rated high in comparison with the average product of the Gulf States.

What, then, are the inducements toward an expansion of cotton culture in California and the possible establishment of cotton factories on the coast to create a home demand?

With the equalization of the prices of labor, in consequence of increased facilities of communication, there certainly is no reason why the home demand for cotton goods on the Pacific coast should not be supplied from home growth and manufacture, and there is reason why it might secure a large share of the Asiatic market, with which it is in the most direct connection.¹

Hilgard referred to plantings of Sea Island cotton in several localities, but in no case was success reported from this type of cotton. In

¹ Hilgard, E. W. Report on the physical and agricultural features of the State of California, with a discussion of the present and future of cotton production in the State. . . p. 76-77. In U. S. Dept. Int., Census Off., 10th Census, v. 6, pt. 2. 1884.

a published newspaper article an ill-advised planting of over 500 acres of Sea Island cotton in Colusa County was mentioned. The cotton had only begun to bloom in October when the crop should have been ripe; yet a few Upland plants that grew in the same field had fruited abundantly. The best results were claimed for Upland short staples from Tennessee and Georgia, but an Upland long-staple variety called "Petit Gulf," from Louisiana, is said to have done well in several places.

Cotton was urged by Hilgard as a better crop than wheat for many of the lands of the central valleys, on the ground of being less likely to lead to exhaustion of the soil, as less likely to lead to harmful concentration of alkali in the surface layers of the soil on account of being a tillage crop, and as needing less water for irrigation purposes than other crops that had been proposed as substitutes for wheat. The point was made that cotton could be exported while alfalfa could not, and that the California grower would have a great advantage over his southern competitor in not having to "fight the grass."

It is evident throughout Hilgard's report that he looked upon cotton as one of the California industries that were sure to develop, and this idea finds very definite expression in the statement that closes his general discussion:

Keeping all these points in view, the writer can not but think that the wider introduction of cotton culture into California is but a question of time, and that in many respects it will serve to improve the agricultural prosperity of the State.

EXTENT OF POSSIBLE COTTON TERRITORY IN CALIFORNIA.

Of new territory readily available for cotton in the United States, California probably has the largest areas. Recent demonstrations of cotton possibilities have been afforded by the beginnings that have been made in the Imperial Valley and the Colorado Valley in extreme southern California, but the San Joaquin and other more northern valleys contain much larger areas of irrigated or readily irrigable land that might be used for cotton. Hilgard estimated that one-third of the agricultural land of the State lay in the central valleys, with an area of more than 17,000 square miles. While only a part of this territory is suited to cotton, it seems not unreasonable to suppose that the central valleys might produce about 10 times as much cotton as the Imperial Valley.

It is to be expected that much of the cotton will be grown on the level lands in the open valley where fruits and other tender crops are excluded by low winter temperatures, but places may also be found for cotton as an additional crop in communities that are now devoted to fruit growing or other industries. Indeed, the best results are likely to be secured, at least at first, in communities that are already

established and well organized on the basis of other crops. Farmers who are familiar with the local conditions and have only to learn the requirements of the new crop are likely to make better progress than those who have everything to learn, as in communities formed of new settlers, some of them with no agricultural experience and others persisting in the use of methods to which they have been accustomed in other regions, but which are not adapted to the special conditions and requirements of the irrigated districts.

NATURAL CONDITIONS FAVORABLE.

That natural conditions of soil and climate very favorable for cotton culture are to be found in the interior valleys of California has been shown again in recent years by the behavior of series of different kinds of cotton that have been grown and studied at several points representing the general range of climatic conditions—Red Bluff, Chico, Marysville, Davis, Stockton, Dos Palos, Visalia, Exeter, Semitropic, and Bakersfield.

The general result of these experimental plantings has been to leave no doubt that cotton is able to make normal growth and mature good crops in the warmer districts of the interior valleys; that is, in the northern part of the Sacramento Valley and the southern part of the San Joaquin Valley. The most successful plantings have been those at Bakersfield and Semitropic in Kern County, and at Dos Palos in Merced County, where the plants were extremely well grown and productive, with bolls of very large size and lint of excellent quality, results that are obtained only under conditions thoroughly favorable for the development of the plants.

Much more extensive experiments would be necessary to determine how far cotton culture might be carried toward the cooler climate of the Bay districts in the central part of the State by using early short-season varieties or selecting for adaptation to the local conditions, but no special difficulties seem likely to be encountered in the warmer parts of the valleys. The cotton plant is able to thrive on a great variety of soils, a moderate but regular supply of moisture being the chief requirement. While the plants are able to survive drought, the crop is likely to be injured by any extreme condition that checks or forces the growth of the plants.

It has to be expected that any undertakings with a new crop, wherever the beginnings may be made, must pass through an experimental period, in order to test fully the possibilities of the soil and local climatic conditions and determine the methods that can be applied to the greatest advantage. The most that can be said at present is that practical experiments with cotton are likely to be justified in any of the warmer districts where soils of reasonable fertility and adequate supplies of water are available.

It is very desirable that experimental efforts in cotton growing be limited to communities in which the general agricultural conditions, as well as the present interests and activities of the community, are such as to give ground for a reasonable expectation that an annual irrigated crop like cotton, if found to thrive, would be likely to become a permanent resource. For a few scattered individual farmers to plant cotton in communities that are not likely to engage regularly in its production is not advisable. It is expensive to ship cotton seed and not worth while to install gins and oil mills unless the production of cotton reaches commercial proportions.

RETURNS THAT MAY BE EXPECTED FROM COTTON.

The first step toward the commercial planting of cotton, or considering it as a practical alternative of any other crop, is to determine whether cotton is likely to be more profitable or at least sufficiently remunerative to be added to the existing series of crops. Undoubtedly the chief obstacle to the production of cotton on a large scale in the San Joaquin Valley and other districts of California lies in the fact that attention has been directed to other industries that have been considered more profitable than cotton growing. While cotton can probably be grown on many lands that are now used only for grain or pasture, it seems reasonable to expect that at least the first beginnings with cotton in new localities will be made by farmers who are already settled on the land and engaged in the production of fruit or other intensive crops.

Even at the highest prices for cotton it should not be expected to compete with the bonanza figures that are sometimes realized from fruit crops. Though acre returns of \$150 or even \$200 are not altogether impossible, they can be obtained only in exceptional conjunctions of very large yields and very high prices, like those that ruled in the season of 1916, when 40 cents and upward per pound was obtained.

The most that can be considered as a reasonable expectation from cotton at moderate, normal prices is a gross return of \$75 to \$100 per acre. This is on the basis of Durango or some other Upland long-staple variety selling between 15 and 20 cents a pound and yielding at the rate of a bale per acre, which requires favorable conditions and good farming. The cost of production per pound increases with every reduction in yield, because the cultural operations and the irrigation water have to be applied to poor-yielding cotton as well as to good.

With a yield of a bale of 500 pounds of lint cotton the cost of picking an acre of the Durango variety is between \$15 and \$20, an amount about equal to the total cost of the previous care of the crop,

so that half of the return, or \$35 to \$50 an acre, may be reckoned as a net gain from the farm operations. With Egyptian cotton, the cost of picking must be reckoned as about double that of Durango, and the ginning of Egyptian cotton is also more expensive, roller gins being required instead of saw gins, which are used for Upland staples. To make good these differences, a premium of 4 or 5 cents a pound for the lint is necessary to render the Egyptian more profitable, but the new and rapidly increasing demand for Egyptian cotton for automobile tires and other industrial uses, and the stationary or declining production in Egypt favor a substantial premium for Egyptian. It may be that yields will average higher with Durango, in view of the fact that Egyptian cotton requires a longer season to mature a full crop, though with favorable conditions Egyptian may yield as much as Durango. Profits of \$150 to \$250 per acre are claimed for growers of Egyptian cotton in the Salt River Valley in 1916, but these must be considered as altogether exceptional and certainly not to be used as a basis of calculation.

It is possible that difficulties may be encountered in providing roller gins in case a greatly increased acreage of Egyptian cotton should be planted in Arizona and southern California in the season of 1917. Roller gins are not made in the United States, but have to be imported from England. The demand for them has been limited in the past to the Sea Island districts of the South Atlantic States.

LABOR REQUIREMENTS OF COTTON.

That the labor requirements of the cotton crop have not been well understood in California may be one of the chief reasons why more efforts have not been made to extend this industry before. The popular idea that large supplies of very cheap labor must be available, as in Egypt, India, China, and formerly in the American cotton belt, has been shown to be erroneous. The last and most striking demonstration of this fact is the establishment of Egyptian cotton production in the Salt River Valley of Arizona. Although labor appeared to cost about 10 times as much in Arizona as in Egypt—\$2 a day, as compared with 20 cents—it has been possible by the use of farm machinery, improved cultural methods, and especially the breeding of better and more uniform varieties of cotton to make good the differences in cost of hand labor.

Egyptian cotton has been grown to advantage in Arizona for several years past, during a period of unusually low prices. The chief difficulty in the newly settled southwestern communities is not that the cost of labor is prohibitive, but that not enough labor is available when needed. This seems to have been the difficulty that was encountered in the early attempts at cotton culture in the San

Joaquin Valley, as it has been in recent years in the Imperial Valley and the Salt River Valley of Arizona. The supply of farm labor now available in the San Joaquin Valley certainly is very much greater than it was half a century ago, when irrigation agriculture was new. How much of the available labor can be applied with advantage to the care and harvesting of a cotton crop is a question that must be decided independently in each community.

Experience gained in Arizona and elsewhere in the United States in recent years does not indicate that the cotton industry requires or is limited to the use of cheap and irresponsible labor. Dependence on such labor tends rather to injure and restrict the development of cotton culture by keeping it on a low plane, limited to inferior varieties and mixed seed, so that poor and uneven lint is produced, the value of which is still further depreciated by careless harvesting and handling.

When the several unnecessary wastes and losses are taken into account and the possibilities of avoiding these are recognized, one is brought inevitably to see that the very best quality of agricultural skill and of careful, intelligent labor can be utilized in the production of cotton and that the industry is much more likely to prosper if it can leave behind the traditions of cheap labor. Hence, it is not necessary to suppose that the establishment of cotton culture in California would increase the present dependence on transient labor. It seems quite as likely to add to the permanent population by making it easier for new settlers to establish themselves.

Farm work with cotton is not of a nature to be considered as heavier or more laborious than with crops that are already grown in California. Methods of plowing, preparation, and seeding are not unlike those for corn or other tillage crops. Thinning and cultivating make less demands than for sugar beets. The gathering of the crop, though representing by far the largest item of labor cost in the production, is neither a heavy nor an unpleasant kind of work in comparison with the harvesting of many other crops. In communities of new settlers or where women and children share in the outdoor work of the farm, the planting by each family of small acreages that could be handled without extra labor would be worthy of consideration. The lint as it hangs exposed in the open bolls is perfectly clean and must be kept in that condition if it is to have the highest market value.

Careless picking diminishes the value of the fiber to the manufacturer because additional labor and machinery are required to clean the carelessly picked cotton and because some of the fiber is turned into waste as a result of the cleaning operations. An estimate of what it costs the manufacturers every year to overcome by machinery and mill labor the results of carelessness and ignorance in the produc-

tion and handling of cotton would run far into the millions, and even into the hundreds of millions. Thus, there is reason to believe that refinements in methods of production and handling, like those that have been worked out in California for fruits and other special products, could be applied with very great advantage to cotton. Although cotton is not a perishable product, its value depends very largely upon the condition in which it is placed upon the market. Taking into account the experience that agricultural communities in California have had in working out and applying special methods of production, handling, and marketing their crops, it would seem that the possibilities of producing cotton of the highest quality and placing it in the market in the best condition are more likely to be attained in that State.

Another advantage of cotton as an element of diversified farming is that it is less exigent than most other crops in demanding labor at particular times. Cotton can be planted early and thinned early or planted late and thinned late if allowance be made by leaving the plants of the later thinnings closer together. Early plantings may be made in March or as soon as the danger of cold weather is past, but the planting may continue through April and May. Even June plantings are sometimes successful.

Unlike fruits and other perishable products that have to be gathered and shipped or cured at once or within a very few days after the proper stage of maturity is reached, cotton can be picked through a long season. The bolls open at maturity, but the cotton remains in place and in dry weather suffers no injury by being left on the plants for a week, or even a month. The picking season may extend over a period of two, three, or four months.

In the interior valleys of California cotton begins to open in September. Picking probably would commence soon after the grape harvest and extend through November or even till Christmas. It is better, of course, not to wait too long after the bolls have opened, for some of the cotton is likely to fall out or become soiled or stained from rain or dust. But even these contingencies, while they reduce the value of the cotton, do not result in total loss, as they would with many other crops.

COTTON CULTURE A COMMUNITY UNDERTAKING.

With general reference to the warmer parts of the San Joaquin and Sacramento Valleys it may be said that the chief question is not whether cotton could be grown or whether its culture could be made as profitable as others that are being followed, but whether there are communities of farmers who will organize for such an undertaking. Some form of organization is a practical necessity for beginning cotton culture in a new region. Unlike many other crops that can

be grown to some advantage even on a very small scale and either used in the household or sold for local consumption, an isolated individual farmer can hope for no advantage from the planting of a small acreage in cotton.

The beginnings of cotton culture in the South Atlantic States can be traced back to the time when spinning and weaving were household industries and cotton was made into cloth and used on the same plantation where it was raised; but with the modern organization of the industry cotton has become a strictly commercial crop, grown only to be sent to market. The effect is to limit the production of cotton to districts where facilities for marketing exist or to communities that can begin cotton culture on such a scale as to enable these facilities to be provided.

In order to send cotton to market it has to be ginned, to separate the seed from the fiber, and packed into bales. For both of these operations special machinery is required; not very expensive machinery, it is true, but too expensive for the individual farmer to install for any ordinary farm acreage of cotton. Unless a community appears likely to plant 1,000 acres or more of cotton the installation of ginning machinery can hardly be considered advisable, either by the community itself or by an independent ginning company. It is not absolutely necessary that large acreages be planted the first year, since the cotton from small experimental plantings in a new community can usually be shipped to some established center where gins are in operation or can be held over in case it is decided to plant on a commercial scale during the next year.

Still larger acreages must be in prospect if a community is to be provided with its own oil mill, which is necessary for disposing of the seed to the best advantage. Oil-mill equipments are more expensive than gins, but they are not beyond the reach of large and well-organized communities, like those that own and operate fruit-packing houses and many similar undertakings in California.

COMMUNITY CONTROL OF GINS AND OIL MILLS.

Control of the gin and oil-mill equipment by the community is very desirable, not only for the financial reason of enabling the growers to secure a larger share of the profits of the industry but also for more directly agricultural reasons. It is out of the question to maintain pure stocks of seed without special precautions that are very seldom observed at privately operated commercial gins. The mixing of different varieties or stocks of seed at the gin is the most frequent cause of deterioration of the varieties, the result being to destroy the uniformity of the fiber and lessen the commercial value of the cotton produced by the community.

The careless ginning of the cotton may seriously impair the value of the fiber, injure the reputation of the product of the community, and keep the farmer from getting a full price for his crop. Long staples are more likely to suffer in this respect than short staples, for there is greater need of careful ginning. Ginning is often considered by oil-mill companies a merely incidental line of business.

Another way in which ill-advised management of oil mills has been known to interfere with the agricultural development of communities is by bringing in and recommending to the farmers seed of inferior varieties in complete disregard of the chief interest of the community on the side of producing superior fiber. In some cases attempts have even been made by the use of financial pressure to force upon farmers the planting of varieties that were distinctly inferior in quality of fiber, but were supposed to promise profits for the oil business.

AGRICULTURAL ADVANTAGES OF COMMUNITY ORGANIZATION.

In addition to the need of special care to avoid mixing seed of different kinds of cotton, there is equal need to prevent crossing in the field, which is likely to occur whenever two kinds of cotton are planted close together or even in neighboring fields. The pollen of the cotton plant is not blown about by the wind, because the surface of the grains is sticky and adherent, but bees and other insects carry the pollen, sometimes for half a mile or more. The closer the fields the greater, of course, is the liability of crossing, so that in thickly settled communities it becomes practically impossible for the individual farmer to maintain a pure stock of a superior variety of cotton.

The simplest and most effective way to avoid these dangers of admixture and deterioration of varieties is for communities to organize for the production of a single variety. The variety should be determined, whenever possible, by preliminary experimental comparisons of the behavior of the more promising sorts grown under the local conditions. The most effective test is to plant several small blocks, consisting of four or five rows of each variety, alternately in the same field, and to record the pickings of each row separately. Such tests are being conducted by the Department of Agriculture in cooperation with communities located in different parts of the cotton belt.

With only one variety grown in the community it becomes possible to preserve its purity and uniformity by selection. It is useless to expect that the fiber will continue to be uniform if the stock is allowed to deteriorate through seed admixture or cross-pollination. This not only lessens the commercial value of the fiber but diminishes the yields, the aberrant plants being less fertile than the normal in-

dividuals. Failure to maintain the purity of stocks is the basis of the popular belief that varieties of cotton soon run out. No variety should be expected to remain uniform unless selection is continued and admixture with other varieties prevented.

In addition to this primary consideration of maintaining the purity and uniformity of varieties, organized communities can deal to better advantage with most of the problems of production and marketing of the crop. Cultural methods are likely to be much better understood and more skillfully applied in a community where only one kind of cotton is grown and differences between varieties are not being confused with effects of cultural methods, soils, or seasonal conditions.

Marketing problems are also greatly simplified in communities that can offer commercial quantities of one superior variety of cotton. The classing of the cotton is a function of the community organization, whether done by local talent or by an expert employed by the community. Classing is necessary not only for selling the cotton at its true value, but for using the bales as security for loans, in case the farmer lacks ready money to meet the cost of picking or wishes to hold his cotton for better prices. Communities that have a regular system of classing and warehousing their cotton are able to arrange for loans on better terms than the individual farmer.

Community action is also very important in relation to insect pests or plant diseases. Measures of protection that can be expected to do very little good if applied only by scattering individual farmers may be rendered very effective if used by the entire community. This is notably true of the precautions that are advised against the boll weevil, but is likely to be equally so with any other parasite or disease that may appear in any district. If only a few of the parasitic insects or diseased plants are destroyed, the farmer who takes the precautions may fare no better than his more careless neighbors, but if it were possible to get action by the entire community the effect of any remedial measure would be definitely shown.

CONCLUSIONS.

Cotton was grown in California half a century ago, but the early attempts were made on a basis of direct competition with the South, which could not be maintained when normal conditions had been reestablished after the Civil War. The present possibilities of development of cotton culture in California lie in the direction of producing Egyptian or other special types of long-staple cotton. The demand for cotton of the Egyptian type is increasing rapidly and not likely to be met by increased production in Egypt, where the crop is endangered by the invasion of a new insect pest.

Experimental plantings in the region of Bakersfield indicate that the Egyptian type of cotton can be grown in the southern part of the San Joaquin Valley. No assurance can be given that Egyptian cotton will mature a crop outside of the Bakersfield-Fresno region. If plantings are to be made in the northern part of the San Joaquin Valley or in the Sacramento Valley, the Durango cotton or other long-staple Upland varieties are more likely to succeed, since they do not require as long a season as the Egyptian.

While cotton makes larger demands for hand labor than many other crops its requirements for attention at particular times usually are not so acute, which renders it well adapted for fitting in with other crops to form practical systems of diversified agriculture. Labor is needed chiefly at the picking season, which comes in the fall after the grapes and most of the other fruit crops have been harvested.

Although favorable natural conditions may be found in many places, it is not advisable to attempt to grow cotton on a commercial scale except in communities that can be organized for this purpose, so as to have an assured prospect of production on such a scale as to warrant the establishment, preferably under community auspices, of the ginning establishments and oil mills that are a part of the necessary equipment of a cotton-producing community.

Farmers in California are advised against undertaking the planting of cotton on a merely individual basis, not only because of the difficulties of handling and marketing a new crop to advantage, but also in order to avoid as far as possible the danger of attempts being made to bring in cotton seed either from the cotton belt or from Egypt. Such importations of cotton seed are now forbidden by Federal and State regulations, the object being to prevent the introduction of the boll weevil from the cotton belt and the pink bollworm from Egypt.

Another reason for advising that efforts to establish cotton culture be centralized in communities is that much more effective cooperation can be extended by the different branches of the Department of Agriculture that have been working in recent years in cooperation with new communities. The nature of the cotton industry is such that many things can be done by communities which are impracticable for the farmer who attempts to grow and market his crop individually.

Efforts to establish the cotton industry in new districts have, of necessity, to pass through an experimental period in order to determine the best variety to be grown, the special cultural methods required by the local conditions, the form of organization adapted to the community, and the most desirable system of handling and marketing, as well as to solve other problems that are encountered in developing new communities.

PUBLICATIONS ON COTTON CULTURE.

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- Factors affecting the production of long-staple cotton. *In* U. S. Dept. Agr., Bur. Plant Indus. Circ. 123, p. 3-9. 1913.
- A new system of cotton culture. *In* U. S. Dept. Agr., Bur. Plant Indus. Circ. 115, p. 15-22. 1913.
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- Martin, J. G. The handling and marketing of the Arizona-Egyptian cotton of the Salt River Valley. U. S. Dept. Agr. Bul. 311, 16 p., 3 pl. 1915.
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UNITED STATES DEPARTMENT OF AGRICULTURE



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WM. A. TAYLOR, Chief



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PROFESSIONAL PAPER

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APPLE BLOTCH AND ITS CONTROL.

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INTRODUCTION.

In the more southern apple-growing sections of the United States the disease known as apple blotch is one of the most destructive with which orchardists have to contend. It first came generally to the notice of plant pathologists about 15 years ago and soon afterwards was regarded as important throughout southern apple-growing sections. As early as 1895 the disease was recognized by Mr. M. B. Waite, pathologist of the Bureau of Plant Industry. He photographed the diseased fruits and determined the organism present to be a species of *Phyllosticta*. His photographs, which are on file in the Office of Fruit-Disease Investigations, show that he was working with typical specimens of the disease. The fact that blotch was previously confused with apple scab by growers, because both of these diseases occur comparatively early in the season, accounts for the rather late recognition of its importance.

Blotch is not so universally distributed, even throughout the South, as scab. While in some sections it will be found in practically every

NOTE.—This bulletin is of interest to plant pathologists and to the apple growers of the eastern half of the United States, especially those of the more southerly apple-growing sections.

orchard, in other sections it is only locally severe. The former is the case in the Ozarks of Missouri and Arkansas and in the commercial apple-growing sections of Kansas, while the latter is true in Virginia and Maryland.

On account of the above-mentioned facts it is very difficult to compute the amount of damage caused by the disease, but it is probable that \$2,000,000 would be a conservative estimate of the annual loss due to it.

In orchards in which blotch has not been placed under control by spraying, the entire crop of susceptible varieties may succumb to the disease and the trees themselves may be severely injured, in extreme cases even killed. Losses of 50 to 75 per cent of the entire crop are common in some sections.

The disease is found in practically all the eastern and middle-western apple-growing regions from Pennsylvania, Ohio, Indiana, Illinois, northern Missouri, and Nebraska southward. It is most serious and widely prevalent in Kansas, southern Missouri, northern Arkansas, Tennessee, and Kentucky. It is also a serious disease in fruit-growing sections bordering on or near the Ohio River. In Virginia and Maryland it is only locally severe, but it has become much more prevalent during the last two years. Blotch has been gradually extending farther north, but should not become serious in properly sprayed orchards. In those sections which have been free from the disease and in which a fungicide such as lime-sulphur solution or Bordeaux mixture is annually applied to apple trees about three weeks after the petals have fallen, blotch should not be able to gain a foothold.

DESCRIPTION OF APPLE BLOTCH.

Blotch occurs on the fruit, foliage, and twigs of the apple.

On the fruit it first appears as small dark, somewhat raised spots, which later enlarge slowly. Usually these spots have in midseason a dark fringed or stellate appearance, though on some varieties, such as Maiden Blush, the center of the spots may be somewhat more raised or blisterlike in appearance and of rather light color, due to the raised cuticle (Pl. I, figs. 2 and 3).

A later phase of this disease on the fruit is the coalescence of several spots, a general homogeneous darkening, with complete elimination of the stellate configuration typical of earlier stages. On some varieties, notably Ben Davis, a cracking open of the fruit often in three directions from a central point, is very common in orchards in which the disease is at all serious (Pl. I, fig. 1).

A characteristic spot is raised, glistening black, with margins so deeply cut in and so irregular as to give the spot its commonly noted stellate appearance (Pl. I, fig. 4). The tissues beneath the epi-

dermis are not invaded directly and are affected only indirectly as the diseased epidermis may permit the entrance of rot organisms or as extensive cracking may affect the flesh. Not only may the fruit be cracked open and otherwise made unsightly by the disease, but in severe cases it may be so dwarfed and distorted as to be wholly worthless. Even on very young spots the tiny glistening pycnidia of the causal fungus are always in evidence.

On the leaves (Pl. II, figs. 1 and 2) the disease appears as small nearly white spots scarcely more than a millimeter in diameter. Usually a single pycnidium of the fungus is to be found near the center of the spot. Under ordinary conditions blotch is not to be considered a serious foliage disease, but in cases where an orchard is severely infected the spots on the leaves are numerous enough to affect seriously the synthesis of carbohydrates and even cause defoliation.

On the young twigs and water sprouts the disease is first noticed as a dark raised area, soon dotted with numerous pycnidia. Later the infected part becomes somewhat sunken. As the twig becomes more mature the infected portion becomes lighter colored, and during the next season the diseased area will appear as an older tan-colored portion surrounded by a newer dark-colored area (Pl. II, figs. 3 and 4). In the older portion the fungus is dead, but in the newer portion it will be found alive, extending the previous year's destruction. In ordinary cases not many twigs are killed and few are badly injured (Pl. II, fig. 6); but in sections in which the disease is severe, and especially on certain varieties, such as the Northwestern (*North-western Greening*), the infection may be so severe as actually to kill the tree.

The fruit spurs may be attacked and in extreme cases even killed. In uncared-for orchards or in orchards in which the disease has been very prevalent and without proper control by means of spraying, many of the fruit spurs may be injured seriously.

CAUSE OF THE DISEASE.

The cause of the disease is the fungus *Phyllosticta solitaria*, first described by Ellis and Everhart (2)¹ in 1895. The type specimen was found on the leaves of the wild crab apple (*Pyrus coronaria* L.). The specific name is suggestive of the tendency of the fungus to form a single pycnidium in each spot on the leaf.

REVIEW OF THE LITERATURE.

In 1902 Clinton (1) published a description of the disease as it occurs on the fruit of the apple and considered it due to an unknown species of *Phyllosticta*. He also noted that pycnidia on the fruit produced fewer spores as the season advanced.

¹ The serial numbers in parentheses refer to "Literature cited," p. 11.

In 1907 Scott and Quaintance (5) described the disease and gave tentative recommendations for its control.

The first extensive report on the life history of the fungus and the first definite recommendations for its control were published by Scott and Rorer (6) in 1907. Later (1909), by comparison with type specimens they identified the fungus definitely as *Phyllosticta solitaria* E. and E. and determined by cross inoculations that the fungus found on leaves, fruit, and twigs is identical. They further determined that the fungus passes from one season to another in small cankers on the twigs.

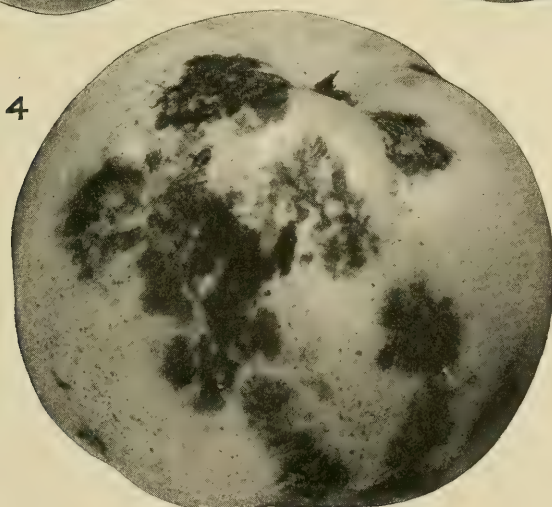
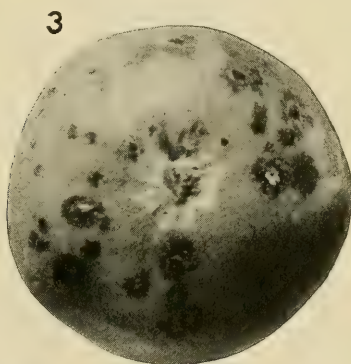
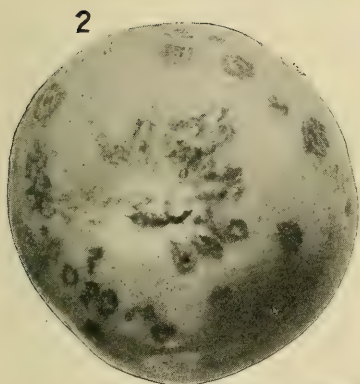
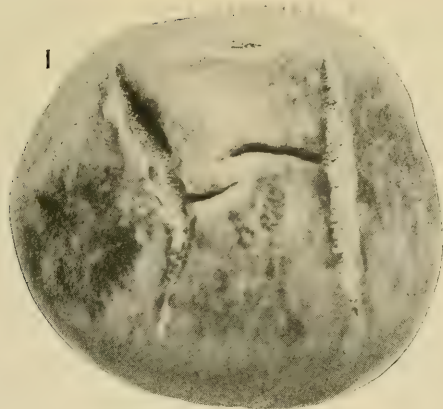
Sheldon (7) in 1907 reported the presence of the fungus on twigs. He was the first to identify the fungus as *Phyllosticta solitaria* E. and E. and gave a good description of the disease on leaves, fruit, and twigs.

Lewis (3) gave a detailed description of the disease on the fruits of different varieties and noted particularly the destruction of fruit spurs.

THE FUNGUS.

The life history of the causal organism has been traced by Scott and Rorer and by Sheldon. They found that the fungus passes the winter alive in the small twig cankers, where it grows and develops spores the following spring. From this source the young fruit, leaves, and twigs become infected early in the season. Later, spores from the spots of apples thus affected may spread the disease farther during the current season.

Scott and Rorer found almost no spores in mummied fruits of the preceding year and concluded that mummies were not a source of the spring infections. At different times during the spring of 1915 the writer undertook to examine for spores something more than a bushel of mummied fruits that had been badly affected with blotch during the preceding year. The varieties selected were Ben Davis and Missouri (*Missouri Pippin*), both of which are very susceptible to the disease. On the average, six blotched areas on each apple, especially selected for the large number of pycnidia contained in them, were examined. The period during which the mummied fruits were collected and examined extended from April 1 to June 1, 1915. The fruits were from trees particularly noted during the preceding year as heavily infected with the disease. It was thought that by examining such specimens at intervals during this period it could be ascertained (1) whether spores remained in the pycnidia through the winter, (2) whether an ascogenous form was produced during the winter or spring, and (3) whether new pycnidia with spores were produced after the growing season started in the spring. All the material was sectioned on the freezing microtome and examined care-



APPLE BLOTCH.

1, Ben Davis apple, showing cracking due to blotch, Bentonville, Ark., August 10, 1914; 2 and 3, Maiden Blush apples affected with blotch, Anderson, Mo., July 8, 1915; 4, Yellow Newtown apple affected with blotch, Greenwood, Va., August 6, 1916.



APPLE LEAVES AND TWIGS SHOWING BLOTCH.

1 and 2, Leaves of the Arkansas Black variety, with spots caused by the blotch fungus, Centerton, Ark., July 31, 1915; 3, 1-year-old blotch canker on Ben Davis apple twig, Bentonville, Ark., 1914; 4, 2-year-old blotch canker on Ben Davis apple twig, Bentonville, Ark., 1914; 5, leaf of the Missouri variety, showing lesions on petiole and midrib produced by artificial inoculation with spores of *Phyllosticta solitaria* from pure cultures; 6, an older blotch canker on a Ben Davis twig, Bentonville, Ark., September 9, 1916.

fully under the microscope. In the old pycnidia no spores were found. No ascogenous stage and no newly formed pycnidia were discovered. The fungus appears to be in no way saprophytic, since not only does it fail to live over on decayed fruits, but it dies out in the older parts of the twig cankers, living only along the margins and dying out entirely in the third or fourth year as the twig becomes more woody.

In order to confirm the cross-inoculation experiments of Scott and Rorer, in which the disease was produced on the fruit by spores from twig lesions and on the twigs by spores from diseased fruits, the writer undertook a series of experiments differing from those of Scott and Rorer in that the latter used spores taken directly from twig lesions and diseased fruits, whereas those of the writer were made with spores from pure cultures from those sources. The fungus isolated from twigs and fruits from Kansas was grown on sterile apple twigs in pure culture, and when the spores were mature a suspension of them in sterile water was sprayed on leaves, fruit, and twigs. Inoculations were made on twigs, water sprouts, and fruits of the Missouri variety on July 6. On August 7 typical blotch spots began to appear on the leaf blades and petioles, with an abundance of fertile pycnidia in the dark sunken lesions on the petioles and midribs (Pl. II, fig. 5). Minute spots on the fruits also were beginning to appear. On September 6 the spots on leaves and fruits were numerous and conspicuous. The disease was beginning to appear also on the twigs and water sprouts. By September 14 lesions on the stem portion of the water sprouts and twigs were appearing abundantly. These were black raised areas, bearing numerous pycnidia filled with spores, and were only on the younger portions of the twigs and water sprouts. The fungus was reisolated from leaves, fruit, and twigs and reidentified as *Phyllosticta solitaria*.

The writer at various times has attempted to infect the fruit in August and September with spores from pure cultures, but without success. Apparently fruit and twigs become resistant as they grow older, possibly through the increasing impermeability of the epidermis and the changing of stomata to lenticels. The heaviest infections on fruit occur early in the season, decreasing as the season advances. This is due, not only to a decrease in the number of spores produced by the fungus in the cankers and fruit, but probably in a much greater degree to the previously mentioned increased resistance on the part of the fruit. The writer has never been able to inoculate fruits of Ben Davis and Missouri after August 1 by spraying them with a suspension of spores in distilled water. It may be noted also that at that time the natural supply of spores capable of infecting is still not wholly wanting in so far as those produced from cankers

are concerned, while many are still produced from the diseased fruits.

It is a rather curious thing that leaf infections are comparatively rare in Arkansas, whereas in Kansas they are rather abundant. This may be partly, though not wholly, accounted for by the more numerous cankers and consequent heavier infection in Kansas orchards.

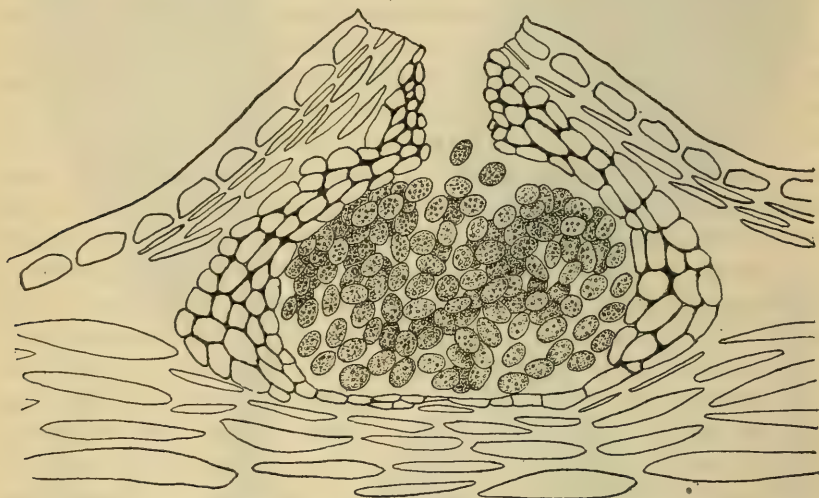


FIG. 1.—Section through a pycnidium of *Phyllosticta solitaria* produced in 1914 on a blotched spot of a young Ben Davis apple.

The fruiting bodies (pycnidia) are found on the newer parts of the twig cankers until the cankers are about 4 years old. They are most plentiful on young cankers which had begun their development during the previous season. They occur on the leaves also, particularly



FIG. 2.—Spores of *Phyllosticta solitaria* from twig cankers of the Ben Davis apple. Bentonville, Ark., May 25, 1914.

in the lesions on the midrib and petiole, and in the blotches on the fruits. The pycnidia (fig. 1) are rather small, black, glistening, sub-globose or somewhat depressed, varying from 75 to 250 μ in diameter. When mature they are filled with spores, but those formed late in the season usually fail to mature. The period of maximum pycnidium production is in May

on the twigs and in late June and early July on the fruit and leaves. Those on the leaves rarely produce spores.

The spores (fig. 2) are hyaline, one celled, and when mature are filled with rather large, uniform-sized, often closely compacted granules. They are oval to subglobose and measure 8 to 10 by 5.5 to

6.5 μ . When newly formed it is easy to demonstrate the presence of a gelatinous covering about the spore, especially when, as is often the case, it is prolonged into a stout hyaline appendage (fig. 2). The spores (fig. 3) germinate in 15 to 20 hours. The germ tube is somewhat darker than the spore and usually shows a pronounced thickening at the point of emergence (fig. 3). More than one germ tube may issue from a single spore (fig. 3).

Spores from the twig cankers in which the fungus has passed the winter are usually mature and ready to infect the young fruit and leaves about three weeks after the petals have fallen. This was first determined by Scott and Rorer by noting the latest time at which spraying would effectively prevent infection. The time of infection was directly determined by the writer during the seasons of 1914 and 1915 by germination tests of spores from twig cankers. Table I shows the results of such tests.

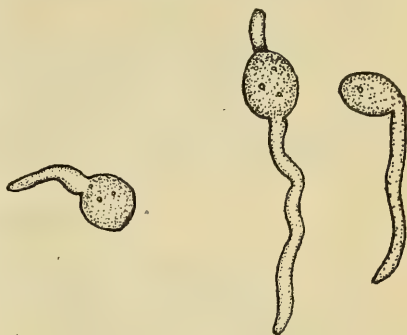


FIG. 3.—Germinating spores of *Phyllosticta solitaria*. Spores from Ben Davis twig cankers, May 25, 1914.

TABLE I.—Results of germination tests of spores of apple blotch from twig cankers.

Date.	Germinating spores.	Date.	Germinating spores.	Date.	Germinating spores.
1914.	Per cent.	1914.	Per cent.	1915.	Per cent.
Apr. 30.....	0	May 15.....	0	May 13.....	10
May 1.....	0	May 21.....	0	May 17.....	20
May 6.....	0	May 23.....	75	May 21.....	20
May 8.....	0	May 25.....	75	May 24.....	75
May 9.....	2	May 29.....	75	May 28.....	75

For each test, pycnidia were scraped from the newer portions (the current year's growth) of young twig cankers. These pycnidia were then examined under the microscope for spores. If spores were sufficiently abundant and appeared to be mature, they were suspended in distilled water in Van Tieghem cells and the percentage of germinating spores was noted daily for periods ranging from three to five days. As the spores when mature usually germinate within 24 hours, it was really unnecessary to prolong the attempted germination over so long a period. The cankered twigs used in this work in 1915 were collected from the same trees as those used in 1914.

During both seasons the time of petal fall was April 28. As these two seasons were about average ones, it is evident that in the Ozarks

the first spraying for the prevention of blotch infections should be well under way when three weeks have elapsed after petal fall. This is particularly true during a season of belated blooming due to cold or otherwise unseasonable weather, as the period of growth and maturity of the fungus and its spores does not seem to be influenced so much by such conditions as does the blooming period of the host.

As determined by artificial inoculations, *Phyllosticta solitaria* grows very slowly and is not perceptible on the fruit until three to six weeks after infection has taken place. Ordinarily the blotched areas are not large enough to appear conspicuous before the early part of July.

* CULTURAL RELATIONS.

Phyllosticta solitaria will grow on a wide range of culture media. It will also produce pycnidia on all of the ordinary solid culture media. These pycnidia, however, do not produce spores. The only medium on which the writer has been able to grow the fungus with the formation of both pycnidia and spores is sterile apple wood, which was the medium used by Scott and Rorer. Even on this medium two to three months elapsed in the case of all the strains used by the writer before mature spores were produced.

WEATHER CONDITIONS.

In orchards in which twig cankers are abundant, dry weather does not appear to reduce greatly the number of infections, because practically every apple is affected anyway; but in the average blotch-infected orchard of the Ozark section the reduction is very noticeable. In 1914 the absence of rain during the latter half of May and during the first three weeks of June greatly reduced the number of infections. In Arkansas the period of heaviest infection did not occur until about July 1. In Kansas, where blotch is a particularly serious disease, it was found, as Lewis had noted previously in dry seasons, that the disease was not greatly hindered by the dry weather. The sources of infection, that is, twig cankers, are much more abundant in Kansas than in Arkansas, and even if a large proportion of the expelled spores failed to germinate there would still be enough to infect the fruit heavily. Undoubtedly, as in the case of most fungous diseases, moist weather is particularly favorable for the occurrence of the maximum number of blotch infections.

The writer has never been able to note any relation between the amount of infection and the temperature extremes during May and June. Neither extreme appears to be particularly favorable or particularly unfavorable.

RELATIVE SUSCEPTIBILITY OF APPLE VARIETIES.

The list of susceptible, moderately susceptible, and resistant varieties shown in Table II is based on the publications of Scott and Rorer and of Lewis and upon the writer's own observations. It often occurs that a variety which is quite resistant and which has no twig cankers of its own will show some infections on the fruit if it is growing in close proximity to a badly infected variety.

TABLE II.—*List of apple varieties, showing their relative susceptibility to blotch infection.*

Very susceptible.		Moderately affected.		Resistant varieties.
Varieties.	Varieties.	Varieties.	Varieties.	
Missouri. Ben Davis. Northwestern. Limbertwig. Maiden Blush. Lawver. Shockley. Clayton. Willow. Arkansas Black.	Gano. Domine. Huntsman. White Pearmain. Smith. Tolman. Fameuse. Wagener. Gilpin.	Oldenburg. Benoni. Arkansas. Bradford. Ingram. Collins. Rambo. Golden Russet. Grimes. Yellow Newtown.	McAfee. Ralls. Yellow Bellflower. Northern Spy. Stayman Winesap. Fink. Minkler. Wealthy. Rome Beauty.	Winesap. Jonathan. York Imperial. Givens.

REMEDIAL MEASURES.

Under ordinary conditions blotch is controlled rather easily by spraying, but under conditions of severe infection the spraying must be done with great promptness and thoroughness. In mild cases control is accomplished by spraying with lime-sulphur solution (32° to 34° Baumé) diluted at the rate of 1½ gallons to 50 gallons of water (or homemade lime-sulphur solution diluted to equal strength), but under conditions of severe infection lime-sulphur solution is not efficient. Under such conditions control is attained through the use of Bordeaux mixture containing 3 pounds of bluestone (copper sulphate) and 4 pounds of lime to 50 gallons of water. Where lime-sulphur gives adequate control it should be used, as it is less likely to injure the fruit and foliage than Bordeaux mixture. The first spraying for the control of this disease should be finished three weeks after the blossom petals have fallen, the second should occur three weeks later, and the third about 9 or 10 weeks after the petals fall.

By thorough spraying for three or four years, the number of twig cankers will be greatly reduced, making control much easier. The old cankers will die out after that length of time, and the coating of spray on the young twigs will prevent the formation of new ones.

In this way Mr. Leslie Pierce, of the Bureau of Plant Industry, and the writer greatly lessened the number of twig cankers and increased the ease of control in an orchard in northwestern Arkansas during 1913, 1914, and 1915.

This orchard, consisting of trees of Missouri, a very susceptible variety, was, prior to 1913, badly infected with blotch. In fact, previous to 1913 the orchard, mainly because of blotch, had not matured a crop. After three years of thorough spraying, done at the proper time, the trees are almost free from twig cankers and the disease is nearly eliminated from the orchard.

Spraying, then, not only prevents the infection of fruits during the current year, but tends also to lessen the number of possible infections during succeeding years. Furthermore, since, as the writer (4) has shown, the bitter-rot fungus may live through the winter in blotch cankers, the elimination of the latter may be an aid in the control of bitter-rot in orchards in which that disease is present.

SUMMARY.

(1) Apple blotch, a serious disease of the more southern apple-growing sections of the United States, affects the twigs, fruit, and leaves of the apple. It has been shown by previous investigators (Waite, Clinton, Sheldon, and Scott and Rorer) to be caused by the fungus *Phyllosticta solitaria*, which, as Sheldon and Scott and Rorer discovered, winters over in twig cankers and infects the young fruit, leaves, and twigs during the following year. Neither Scott and Rorer nor Lewis considered mummied fruit of the previous year an important source of infection.

(2) The writer has made successful cross inoculations on fruit, leaves, and twigs from pure cultures of the fungus obtained from naturally diseased fruit and twigs, thus confirming the inoculation work of Scott and Rorer, which, however, was not done by the use of pure cultures.

The reason so few infections occur late in the season is due to the increased resistance of the host, in addition to the fact that there is a gradual decrease in the number of spores produced by the causal fungus. A large number of mummied fruits were examined at intervals throughout the spring, but no spores were found. Hence it is concluded that mummies are not an important source of infection.

Wet weather favors blotch, but in orchards in which twig cankers are abundant the disease is not checked effectively by dry weather.

(3) The disease is controlled by three sprayings with 3-4-50 Bordeaux mixture at intervals of three weeks, the first of which should be completed about three weeks after the blossom petals have fallen. Summer-strength lime-sulphur solution may be substituted for Bordeaux mixture where the disease is not severe, thus lessening the risk of injury. The proper time for the first application has been determined both by spraying experiments and by spore germination tests in the laboratory. This spraying schedule differs only slightly from that originally worked out by Scott and Rorer.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 535

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.



June 28, 1917

THE HORSE-RADISH FLEA-BEETLE: ITS LIFE HISTORY AND DISTRIBUTION.

By F. H. CHITTENDEN, *Entomologist in Charge of Truck Crop and Stored Product Insect Investigations*, and NEALE F. HOWARD, *Specialist*.

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INTRODUCTORY.

Nearly every year there is brought to this country some insect immigrant, and frequently, in the course of time, these immigrants prove to be pests. As a rule, they are introduced through the large seaports, particularly Boston, New York, New Orleans, and San Francisco, from which points they spread westward, northward, or southward, and less frequently eastward. Occasionally such an insect is carried by commerce beyond the coasts and makes its first appearance inland. This happened in the case of the insect to which the senior author has given the name of the horse-radish flea-beetle (fig. 1) and which is known zoologically as *Phyllotreta armoraciae*

NOTE.—Horse-radish is widely cultivated in the United States and especially where the horse-radish flea-beetle is now most injurious. The farm value of horse-radish is not far from \$400,000 per annum, considering its growth for home use. Two other insects than the horse-radish flea-beetle are especially attracted to it, the horse-radish webworm (*Plutella armoracia* Busck) and the horse-radish caterpillar (*Evergestis straminealis* Hübner). Neither of these is of any importance, but in the southern range of growth of horse-radish the harlequin cabbage bug is a most destructive pest, seeming to prefer this plant to other crucifers. The horse-radish flea-beetle will continue to spread and soon become a dangerous pest unless growers practice methods of control.

Koch.¹ It was obtained for the first time in 1893 on the withered leaves of horse-radish in a vacant lot within a fourth of a mile of the grounds of the Columbian Exposition at Chicago, Ill. It is possible that the species was actually introduced at about that time, but probably the time was one, two, or more years earlier, and it was not reported as a pest until 1908.

The larvæ as well as beetles live on the leaves and petioles of the common horse-radish ([*Nasturtium*] *Radicula armoracia*) and when numerous injure the plant to such an extent as to reduce materially the root crop. The larvæ mine the petioles or midribs (fig. 2), while the adults feed on the leaves, causing the characteristic flea-beetle injury—withering and dying—or gouge deep pits in the petioles or midribs.



FIG. 1.—The horse-radish flea-beetle (*Phyllotreta armoracine*): Adult. Greatly enlarged. (Original.)

This beetle belongs to the same genus as the well-known injurious striped cabbage flea-beetle (*Phyllotreta vittata* Fab.) but may be distinguished readily from all other species occurring in this country by its elytra or wing-covers, which are mostly of a pale cream color with a comparatively narrow sutural black stripe, as shown in figure 1.

The horse-radish flea-beetle, having recently become an economic factor in the growing of horse-radish² on a commercial scale in Brown County, near Green Bay, Wis., the junior author has been able to trace its life economy and history. It first appeared in sufficient numbers to be seriously injurious in the summer of 1914, when it was reported and observed by Prof. J. G. Sanders. In the two years following, the beetles reappeared in large numbers in the same locality.

While as yet not very generally distributed and confined to attacks on the relatively unimportant crop of horse-radish, the possibility that this insect in its new domain may adapt itself to the other and more important members of the cultivated cruciferous plants renders it worthy of such notice as can be supplied.

¹ Order Coleoptera, family Chrysomelidae, subfamily Halticini.

² The authors desire to acknowledge the cooperation of the Department of Economic Entomology, University of Wisconsin, and the many favors received from Mr. George B. Smith, Green Bay, Wis., on whose farm the junior author was stationed when many of the data in this paper were obtained.

DESCRIPTIVE.

THE ADULT.

In appearance *Phyllotreta armoraciae* is distinct from any species of flea-beetle belonging to or introduced into this country. It is somewhat larger and wider than any of the native species of the genus. It is of oval form, strongly convex, and black in color. The first three antennal joints, the apices or tips of the four anterior femora, the tibiae, and the tarsi are reddish yellow. The elytra are very light yellowish, or cream color, nearly white, with a very thin black lateral margin and a broadened sutural stripe, widest at the middle and constricted at each end and extending from the base of the thorax to the apex of the elytra, where it joins the lateral line. The frons or front is very finely, and the prothorax and elytra densely, punctate. A sensitive pore from which proceeds a seta is located on the lateral margin, which is behind the anterior angle. In the male the fourth antennal joint is slightly thickened and longer than the fifth. In the female the fourth and fifth joints are equal.

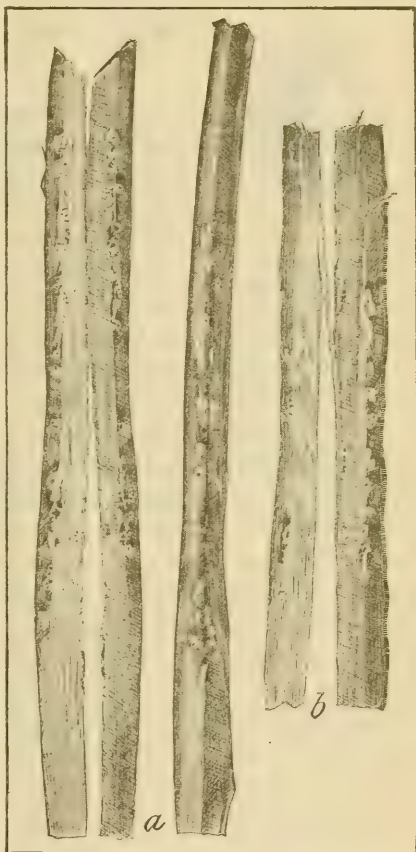


FIG. 2.—Work of the horse-radish flea-beetle in leaf petioles of horse-radish. (Original.)

The average length is from 3 to 3.3 mm., but individuals have been observed where there is a variation of from 2.6 mm. to 3.4 mm. and a variation in width of 1.3 mm. to 1.9 mm.

The following synonymy is recognized:

Phyllotreta armoraciae (Koch).

Haltica armoraciae Koch, Entom. Hefte, v. 2, p. 75, 1803.

Haltica vittata Steph., Mandibulata, p. 292, 1831.

The species is also treated systematically by Illiger, Duftschmidt, Gyllenhal, Schilling, Redtenbacher, Seidlitz, Foudras, Allard, Leesberg, and others.

THE EGG.

The egg (fig. 3) is oval, capsule-like, deep orange in color, with no special characteristic marking or reticulations visible under a 4-millimeter objective. The following are the measurements taken from 22 eggs: Maximum, 0.47 mm. by 0.84 mm.; minimum, 0.26 mm. by 0.43 mm.; average, 0.33 mm. by 0.57 mm.



FIG. 3.—The horse-radish flea-beetle: Egg. Highly magnified. (Original.)

THE LARVA.

The immature larva.—The larva, just after hatching from the egg, is about 1.3 mm. long by 0.2 mm. wide; the color of the entire body is whitish, the head, thoracic plates, and anal plate varying from whitish to pale brown. Within a few hours the head, thoracic plate, and anal plate become darker, and a day or more later turn deep brown. In other major respects, excepting the numerous transverse wrinkles and the relative proximity of the setæ, the young larva is very similar to the older larva.

The mature larva.—The larva (fig. 4), when full grown, is slender subcylindrical, pale yellowish white, with dark brown head, thoracic plate, and anal plate; mandibles distinctly quadridentate; head with the usual V-shaped epicranial suture and dark median line caused by attachment of tentorium; five setæ on epicranium each side of median line, several setæ distributed irregularly about lateral margins of head as shown in figure 4; thoracic plates divided by distinct suture; row of three setæ along anterior lateral margin of each plate; one on lateral posterior angle; four minute setæ on posterior inner margin of each plate; one seta on inner anterior angle; mesothorax with pale chitinous plates bearing setæ, two in anterior row, four in posterior row, four on slightly elevated pleural area; metathorax similar. The thoracic legs each bear one claw.

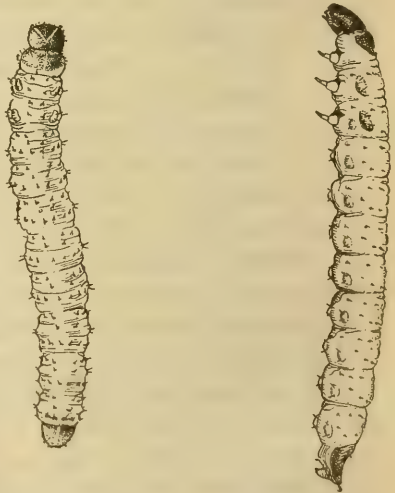


FIG. 4.—The horse-radish flea-beetle: Larva; at left, dorsal view; at right, lateral view. Tubercles and tuberculiferous hairs more prominent than in nature to show arrangement. (Enlarged.) (Original.)

The abdominal segments bear dorsally three rows of slightly elevated chitinous plates, each of which gives rise (when not continuous) to a seta; the first row comprises six, the middle row two, the

third row four; at the ends of the third row, a little anterior, are the slightly elevated chitinous pleural plates, bearing three setæ each.

The anal plate approximates a rectangle in outline with the sides converging toward the posterior end and corners rounded. The whole surface except the chitinous plates is covered with minute granulations.

The length just prior to pupation is 4.8 mm., the width 0.8 mm.

THE PUPA.

The pupa (fig. 5) is white and about the same size as the mature beetle. The antennæ are placed along the dorsal margin of the wings and extend around on the ventral side about one-half way to the middle of the body. Between the wings, which extend down to the fourth abdominal segment, is a narrow space in which the tarsi of the three pairs of legs are placed. The femora and tibiæ of the anterior pairs of legs are parallel and extend transversely across the body over the wings, while these parts of the posterior pair of legs extend obliquely and are under the wings, the tips being just visible. Two forceps-like chitinous processes occur at the apex or tip of the last abdominal segment; a stout seta on the tip of each femur, and a number of setæ at various points on the head and body.

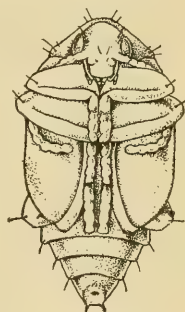


FIG. 5.—The horse-radish flea-beetle: Pupa, ventral view. Enlarged. (Original.)

DISTRIBUTION IN NORTH AMERICA.

The following is a list of localities in which the horse-radish flea-beetle is known to occur in North America. (Fig. 6.) This list is given in approximate order of the first noted appearance of the insect, with the name of the collector in each case:

- Chicago, Ill., 1893 (Chittenden).
- Guttenberg, Iowa, 1894 (Hugo Soltau).
- Okauchee, Wis., 1896 (Dr. E. G. Love).
- Dane County, Wis., 1900 (Dr. Wm. S. Marshall).
- Bloomington, McLean County, Ill., 1900 (Wolcott).
- Glencoe, Ill., 1908 (J. E. Fehd).
- Milwaukee County, Wis., 1908 (Dr. S. Graenicher).
- Whitewater, Wis., 1909 (Univ. Wis. Coll.).
- Westmount, Quebec, 1910 (A. F. Winn).
- Lake County, Ind., 1910 (Wolcott), (Blatchley).
- Shermerville, Ill., 1912 (Retzinger).
- Chester, N. J., 1913 (H. O. Marsh).
- Green Bay, Wis., 1914 (J. G. Sanders), 1915 (N. F. Howard).
- Highland Park, Mich., 1915 (L. Miller).
- Omaha, Nebr., 1915 (Ehlers).
- Potsdam, N. Y., 1915 (Chas. Dury).
- Ashtabula County, Ohio, 1915 (Robt. Sim).
- Madison, Wis., 1916 (N. F. Howard).

ORIGIN AND DISSEMINATION.

The horse-radish flea-beetle is of European origin, and was first described by Koch in 1803¹ from Germany. It is a well-known species in the Old World, and its specific name is derived from its favorite food plant (*Nasturtium*) *Radicula armoracia*. Like all of the striped flea-beetles of the true genus *Phyllotreta*, the present species breeds on cruciferous plants.

As to the means of introduction of this species in the heart of this country, it was probably brought in with horse-radish and less probably in marsh cress (*Radicula palustris*), or possibly with some potted plant. It is not impossible that these plants were brought to America expressly on account of, if not actually for, exhibition at



FIG. 6.—Map showing present known distribution of the horse-radish flea-beetle. (Original.)

the Columbian Exposition. It is remarkable, however, in being introduced, not near a seaport, but so far inland.

In the place of its nativity this species ranges throughout middle Europe. Among early records of its establishment in the United States are Guttenberg, Iowa; Chicago and Bloomington, Ill.; and Okauchee, Wis., about 30 miles due west of Milwaukee, and in 1896 there was a strong probability that it would soon spread to Missouri and perhaps to southern Minnesota and Michigan—in other words, that it would establish itself in the course of time in the upper Austral and, perhaps, a portion of the Transition region in the vicinity of its known range at that time. This would include Nebraska in the West and Ohio in the East. The natural progress of most insects introduced from Europe is westward, but there are several

¹ Numbers in parentheses refer to "Bibliography," p. 15.

examples, notably the Colorado potato beetle, of an insect pest which has first traveled eastward.

The predictions made in 1896 that the horse-radish flea-beetle probably would spread soon to southern Minnesota and Michigan were practically correct, as the species is known to be near the State line of Minnesota in Iowa. It had reached Michigan by 1915 and had spread to Ohio and Nebraska the same year. That it would take an eastward sweep as far as Potsdam, N. Y., Quebec, Canada, and northern New Jersey was scarcely expected for years to come. It is now near the border line of Pennsylvania and will undoubtedly spread to that State and to southern New York. The tendency is northward rather than southward, Bloomington, Ill., being the most southerly locality from which it has been reported.

Until otherwise known (and there is little likelihood of learning anything more definite with regard to the first appearance of the horse-radish flea-beetle), it must be concluded that this species was introduced first into Illinois in or around Chicago. From this center it has spread westward and northward, and has evidently taken large commercial jumps eastward, or has been introduced into New Jersey independently, but has made little progress to the south. From present knowledge it apparently prefers the regions about the Great Lakes, but in time doubtless it will be quite as numerous in other waterways and tributaries, even in moist places generally, which are the natural habitat of its principal food plants—horse-radish and marsh cress. In the course of time the somewhat scant records doubtless will be greatly enlarged, showing thereby a more general distribution than is known at present. It has been remarked that in Wisconsin, in the Green Bay region, conditions for the development of this species are highly favorable. This is in the northern portion of the Transition Life Zone, while Quebec is in the Canadian portion of the Boreal Zone.

REVIEW OF LITERATURE.

An account of the horse-radish flea-beetle was given by the senior author in 1895, which is now out of print (3).¹ In this article mention was made of the first occurrence of the species in this country and of the European literature, and the insect was compared with other species of its genus. The original technical description was published in 1803 (1). In 1893 Julius Weise (2) gave a systematic and detailed description of the species with biologic notes and bibliography. In 1897 (4) the senior author noted the occurrence of this insect in Wisconsin in 1896 and suggested the probable range

¹ Figures in parentheses refer to Bibliography, p. 15.

of the species. In 1900 A. B. Wolcott (5) made mention of the capture of the beetle at Bloomington, Ill. Injury by this species was briefly mentioned by J. J. Davis in Illinois in 1910 (6). In 1910, also, Blatchley (7) recorded its occurrence in Lake County, Ind., and in 1911 A. F. Winn (8) observed it at Westmount, Quebec, Canada, on horse-radish received from Montreal. It is not stated, however, whether the insect was believed to come from Montreal or from Westmount. In Europe brief notes were published by Heikertinger in 1911 and 1912 (9, 10).

FOOD PLANTS.

This beetle is partial to horse-radish and marsh cress. It was taken once on young cabbage in hotbeds in early spring by the junior author but was not observed to be eating. The future no doubt will reveal the possibility at least of other host plants.

SEASONAL HISTORY.

THE EGG.

The eggs are deposited from the latter part of April or early May through spring and summer until early August. The manner of placing and the position are variable, but the preferred location is on the tender petioles of young leaves, in the crevices where they leave the root. A few eggs have been found on the ground and on different places on the leaves, above and below the ground, and also carefully placed in the pits made in the stems and petioles by the larvæ or adults. They usually occur in small masses, either carefully arranged side by side in single rows, or two rows high, or carelessly piled without order. Occasionally an egg is found standing on end. The attachment to the plant is not very secure and often an egg-mass falls on the slightest disturbance. In the cages from 2 to 26 eggs were laid at intervals by a single female. While the most frequent number of eggs deposited was 22, at times 44 were deposited, indicating that about 22 eggs are developed in the ovarian tubes at one time. Copulation often takes place between deposition of batches of eggs, but it has not been determined whether or not this is necessary before the deposition of each batch. Judging from analogy, however, it may not be necessary. Hundreds of eggs were obtained in the insectary, but the egg record of one gravid female (Table 1) will suffice to show the egg-laying capabilities of the species. This female was placed in a vial with a portion of horse-radish leaf May 1, 1915, and the total number of eggs laid was 418.

TABLE 1.—*Egg record of a single female horse-radish flea-beetle.*¹

Date.	Number of eggs deposited.	Remarks.
May 17	22	
27	22	
28	17	
June 3	23	Within 48 hours.
7	26	
8	2	
14	4	
17		Male added.
21	25	
22		Copulating.
25	44	Within 48 hours.
27	24	
29	44	Within 48 hours.
30		Copulating.
July 1	28	Hatched July 12.
2	21	
3	22	
12	39	Within 72 hours.
14		Mass; not counted; estimated at 22.
17		Copulating; eggs laid about July 11 hatched.
18		Copulating.
22	7	Copulating; within 36 hours.
30	26	Within 5 days.
Aug. 3	22	Within 72 hours.
7		Female dead; male still alive.

¹ Within 24 hours in each case, unless otherwise mentioned, eggs were always removed.

Incubation.—The incubation period of the egg varied from 7 to 14 days, as the following data show:

TABLE 2.—*Incubation period of eggs of horse-radish flea-beetle.*

Number deposited.	When deposited.	Date of hatching.	Incubation period.	Larvæ working.
20.....	May 1.....	Before May 17....	<i>Days.</i> 14 (approximate)....	May 17.
(.).....	do.....	May 11.....	10.....	
39.....	May 11.....	May 25.....	14.....	
28.....	July 1.....	July 12.....	11.....	
	July 10, 11, 12....	July 17.....	7 (approximate)....	
13.....	June 27.....	July 4 or 5.....	8 (approximate)....	

The months of May, June, July, and August were from 3.6° to 5° F. below normal.

THE LARVA.

On hatching the young larva crawls about the leaf for some time. Several individuals, observed over an hour, showed no particular course. Some went up toward the tip, others toward the crown, where they were lost from sight, but none started feeding. A small, tender petiole, recently invested by numerous larvæ, showed that they had entered at different places along the inner side.

As the larvæ grow and feed in the tissues of the petioles and mid-ribs of the leaves, their presence is indicated by darkened or dead areas, where they have approached the surface. When the larvæ are

very numerous, the petiole is tunneled to the extent that it shrinks considerably and causes the leaf to wither and die at the tip and about the margins. When the larva is ready for pupation, it leaves the petiole and enters the ground. The exit holes, which soon collapse and appear as brown spots, are also characteristic of larval injury.

When both larvæ and adults occur together, the former are the more injurious. The injury which the adults cause to the young shoots early in spring as they are breaking through the soil is possibly more serious than subsequent injuries.

That the larva may live in the roots of the plant has been clearly demonstrated since it was first reported to the senior author. A potted plant died and was left intact for about a month. When the pot was wanted for another experiment the soil was found to contain several larvæ and pupæ. Only the shell of a root remained, the contents having been completely devoured by the larvæ. The pupæ transformed to normal adults shortly afterward. This habit of descending to the roots is not very general, however, for it has never been observed while roots peeled for the shredder were being examined.

After leaving the plant the larva enters the soil to a depth of from one-eighth to one-fourth of an inch or even 3 inches. Here it remains for 4 or 5 days, when it becomes white and short and thick. In this form it is inactive. From 2 to 6 days, usually 3 or 4, intervene before pupation.

The total larval period of an individual which was deposited as an egg on May 1, and which was hatched about May 15, was 48 days (about May 15 to about July 6). Another required 52 days; two others required about 57 days, two others 64 days, and two others 66 days.

The two larvæ which developed in 48 and 52 days, respectively, each remained 10 days in the pupal stage. Three other individuals also passed the pupal stage in 10 days, but one required 12 days, while three required from 12 to 13 days.

On September 11, 1915, a few pupæ in the cages had not yet transformed. April 17, 1915, the adults were already numerous about the ground where the shoots of horse-radish were just appearing, or about to appear.

This flea-beetle, like others of its kind, and like most leaf-beetles, hibernates in the adult stage. Careful search for pupæ from time to time practically proves this.

In Wisconsin only one generation appears annually.

The total period of time from egg laying to adult ranges from 77 days to about 90 days in the cases where complete records were obtained. Repeated attempts to obtain eggs from the adults of the current season failed.

The length of the egg-laying period, as shown by the record of an individual given above, is about 75 days, from the middle of May to the first of August. It is certain that this beetle emerged in 1914, probably in August or the first of September, and it is fair to assume that the species would have lived longer in nature had it not been killed by predators, parasites, disease, or the like. This shows the species to be exceptionally long-lived, living about a year in the adult stage.

The fact that the males are as long lived as the females may possibly be due to the fact that copulation is necessary at intervals during the egg-laying period.

RECORD OF EXPERIMENTS IN 1916 AT GREEN BAY AND MADISON, WIS.

April 24, a pair of beetles confined with horse-radish plants.

April 30 to May 5, copulation observed.

May 11, 15 eggs deposited within 24 hours or less.

May 12, 12 eggs in fold of leaf; might have been overlooked the day before.

May 17, 31 eggs found deposited since May 12.

May 22, 24 eggs found over Sunday, about 48 hours.

May 24, 20 eggs and copulation observed.

May 25, 25 eggs observed.

May 29, 48 eggs obtained over Sunday in about 48 hours.

May 31, moved to Madison, Wis.

June 4, 66 eggs obtained since May 30; copulation observed.

June 9, 44 eggs, approximately, observed since June 4.

June 14, 60 eggs found in 24 hours.

June 15, 49 eggs seen in about 24 hours.

June 21, 27 eggs obtained since June 15.

June 24, 44 eggs seen in 24 hours.

June 27, 48 eggs deposited within 24 hours or less. At this point the observations were discontinued.

HATCHING RECORD.

The same difficulty which was experienced in 1915 in the hatching of the eggs was observed this year. Of the entire number of eggs obtained from the female whose record is given above, a total of 513, the following hatched:

June 4, 1 egg deposited May 17 hatched, 17 days.

June 9, 1 egg deposited May 17 hatched, 22 days.

June 14, 7 eggs deposited June 9 hatched, 7 days.

As noted in the table of the 1916 records (Table 3), some of the larvæ died and only a few of these cases are mentioned; the remainder, being unimportant to the records, are not recorded. All dates on which observations were made are given.

TABLE 3.—*Life-history record of the horse-radish flea-beetle during 1916.*

Date eggs laid.	Date larva leaves plant.	Egg and larval stages.	Date of pupation.	Pre-pupal period.	Date of emergence.	Total pupal period.	Egg to adult.
		<i>Days.</i>		<i>Days.</i>		<i>Days.</i>	<i>Days.</i>
	July 20	52	July 20		Died.		
	21	53	27	6			
	21	53	27	6	July 31	10	63
	24	56	27	3	31	7	63
	24	56	28	4			
			24		Died.		
	July 27	59	31	4	Aug. 5	9	68
	27	59	31	4	7	11	70
	27	59	31	4	7	11	70
	27	59	31	4	2	7	66
	27	59	31	4	Died.		
	27	59	31	4	Died.		
			27		July 31 ¹		63
			27		31 ¹		63
			31		Aug. 5		68
	Aug. 28	60	Aug. 2	5	5	8	68
	28	60	2	5	Died.		
	28	60	3?	6	Died.		
	31	63			Aug. 5	6	68
	31	63	5	5	13	13	75
	31	63	5	5	13	13	75
	31	63	5	5	13	13	75
	31	63	5	5	13	13	75
	Aug. 2	65	7	5	Died.		
May 29 ¹	2	65	9	7	Died.		
	2	65					
	2	65	Died.				
	5	68	Aug. 7	2	Died.		
	5	68	9	4	Died.		
	5	68					
	5	68	Died.				
	5	68	Died.				
	5	68	Died.				
	5	68	Died.				
			Aug. 5		Died.		
	Aug. 7	70	Aug. 13	6	Died.		
	7	70					
	9	72	Died.				
	9	72	Died.				
	9	72	Died.				
	9	72	Died.				
					Aug. 7		70
	Aug. 13	75	Aug. 20	7	Died.		
	13	75	20	7	Died.		
	13	75	20	7	Died.		
			13		Aug. 20		83
			13		Died.		
					Aug. 20		83
					20		83
			20		25?		88 ¹

¹ Approximate.

SUMMARY OF TABLE.

Average combined egg and larval stages	days.. 61.4
Average prepupal period, 30 individuals	do... 4.9
Average total pupal period, 12 individuals	do... 10
Average egg to adult, 20 individuals	do... 71.8

OTHER RECORDS.

Appearance record: First observed on leaves of horse-radish just breaking through the ground at Green Bay, Wis., April 20, 1916.

Copulation first observed May 2.

RECENT INJURY.

An account of recent injury by the horse-radish flea-beetle was received from a correspondent at Shermerville, Ill., who wrote January 3, 1917, substantially as follows, and who, later, furnished specimens:

I should like your advice on an insect which destroys my horse-radish. It is causing thousands of dollars loss every year in this community, and there seems

to be no way to destroy it. It is very small, yellow with black stripes, and it hops; inside of the leaves there are about 25 or 50, according to the size of the leaf. They do their damage when the horse-radish first sprouts after planting, eating off the sprouts as they come up. We have for years hauled out all old dead leaves, after marketing the horse-radish, and burned them. Paris green kills the leaves; kerosene solution does not kill the bug. Every year I plant about 35,000 plants, and the last two years only about 8,000 developed; besides the loss, I have less and less plants each year. There are several planters who have lost their entire crop on account of this insect.

NATURAL ENEMIES.

No parasite or disease of any sort has been observed in the field or in confinement. This is undoubtedly an oversight, since other flea-beetles have natural enemies, such as parasites of the adults, and in time these will probably come under observation. From Glencoe, Ill., a larva apparently predacious on the larva of this species was received.

ASSOCIATED INSECTS.

Associated with this species at Madison, Wis., were three species of minute maggots, (*Elachiptera*) *Crassiseta nigriceps* Loew, *Oscinis pallipes* Loew, and *Agromyza scutellata* var. *variegata* Meig. The first was found in horse-radish stems with the flea-beetle, and adults were reared from larvæ boring in the same stems, often in the same tunnels, as the flea-beetle larva. The third species was reared in horse-radish flea-beetle rearing cages with the preceding. This and probably one or more related species have often been reared from horse-radish stems both at Green Bay, Wis., and Madison, Wis., but just what part they play in the economy of this beetle is unknown. The adults frequently annoy the beetles by flying around and apparently attempting to alight on them.

METHODS OF CONTROL.

SPRAYING.

The injurious flea-beetles of the group to which this species belongs have never been satisfactorily treated by means of insecticides, to the knowledge of the authors. The same applies to other groups of small flea-beetles which attack solanaceous plants, like potato and egg-plant. The powerful hind legs which enable these insects to jump like fleas assist them in escaping from plants during spraying operations, and it is a matter of general knowledge among practical entomologists that it can not be very well determined how much poison, if any, they obtain by feeding on the poisoned surface of leaves. Many experiments have been made, and in practically every case the results have been negative. On the other hand, where Bor-

deaux mixture has been applied, the flea-beetles of different groups are nearly always repelled. It is evident that arsenicals repel, but in the case of flea-beetles Bordeaux mixture is more effective, a fact which has been known for many years.

During the season of 1914, when injuries by the horse-radish flea-beetle in Wisconsin were very serious and the root crop was much reduced, it was found necessary to bring roots from farther south to supply the usual trade. At this time arsenate-of-lead paste, $6\frac{1}{2}$ pounds to 50 gallons of water, was used four times with considerable success. In the spring of 1915 the field was plowed, the roots collected, stripped of every vestige of leaves, and planted about a quarter of a mile from the old bed. This reduced the beetles to such an extent that very little injury was apparent until the middle of June, 1915.

On June 23 the plants were sprayed with arsenate of lead, and the numbers were reduced considerably. About three weeks later the poison was applied again. In the latitudes of Wisconsin, Michigan, Ohio, Pennsylvania, Delaware, New York, Indiana, and Iowa the spray should be administered at intervals from about the last week in April until late in July.

VALUE OF CULTURAL PRACTICES.

The importance of the employment of methods for the control of these insects as pests is exemplified by the experience of a firm at Green Bay, Wis. Before the advent of flea-beetles, truckers were able to raise horse-radish on a large scale from the same beds for several years at a time, but now the abundance and destructiveness of this flea-beetle makes it necessary to change these cultural practices completely in order to produce a crop, and it is necessary to replant a new bed from old roots every season.

SUMMARY.

The growing of horse-radish in the North is menaced by the introduction from Europe of a small insect known as the horse-radish flea-beetle. The beetle is oval in outline, about one-eighth of an inch long, with yellow elytra or wing-covers bordered with black, and with a longitudinal black band through the middle. The larvæ or young bore into the petioles or midribs of horse-radish, and the adults feed on the leaves and gouge deeply into the midribs, causing drying and death.

The beetle was first recognized in this country at Chicago, Ill., in 1893, since which time its area of distribution has increased until it now occurs from New York and New Jersey to Quebec, Canada, and westward to Nebraska.

The species passes the winter in hibernation as a beetle, coming forth in its northern range in April and May.

While as yet destructive only to horse-radish, its capabilities of becoming a pernicious pest, should it adapt itself to the economically more important cruciferous crops, must be acknowledged, and measures should be taken for its suppression wherever possible.

No systematic control program has been adopted as yet. Bordeaux mixture, a powerful repellent against flea-beetles, applied on the first appearance of the insect will prevent much injury, and if arsenate of lead is used later it should hold the insect in check.

When a new bed is to be planted a location should be chosen as far removed as possible from any infested bed. It is advisable also to destroy all volunteer plants, not only to keep the insect in check but in some cases to suppress it as a weed.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 536



Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

January 26, 1918

THE MEDITERRANEAN FRUIT FLY IN HAWAII.

By E. A. BACK, *Entomologist*, and C. E. PEMBERTON, *Assistant Entomologist*,
Mediterranean and Other Fruit-fly Investigations.

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INTRODUCTION.

The Mediterranean fruit fly (*Ceratitis capitata* Wied.) (fig. 1; Pl. 1, fig. 1) since its discovery in the Hawaiian Islands in 1910 has caused a serious and permanent check upon horticultural pursuits in these islands. The history of this pest shows that it has been gradually spreading to all tropical and subtropical countries. The frequency with which infested fruits from Hawaii are being discovered and condemned at California ports by representatives of the Federal Horticultural Board indicates that this fruit fly might have become established in parts of California and in our more Southern States and might now be doing untold injury to fruit interests but for the efficient quarantine maintained on the Pacific coast by State and Federal authorities. It is feared, however, that the Mediterranean fruit fly ultimately will be able to find some unavoidable weakness in the quarantine work and eventually become established on the mainland of North America.

The investigations reported in this publication have been carried on by the Bureau of Entomology, United States Department of Agri-

¹ It has been found necessary to omit a bibliography consisting of about 350 references accompanied by brief résumé material. Reference should be made to Silvestri, Bulletin No. 3, Hawaiian Bd. Agr. and Forestry, for the most complete printed bibliography.

culture, under the immediate supervision of Mr. Charles L. Marlatt, assistant chief of the bureau and chief of the Division of Tropical and Subtropical Fruit-Insect Investigations. This work was undertaken during September, 1912, primarily to make available for mainland fruit-growing interests information that will prove of inestimable value in determining the extent of the possible distribution of this pest and the factors of control which will be most important in eradicating newly discovered outbreaks.

The senior writer wishes to acknowledge his obligations to Mr. Marlatt, who has greatly aided these investigations by his direction, and to express his appreciation of the assistance rendered by his associates, Messrs. C. E. Pemberton and H. F. Willard.

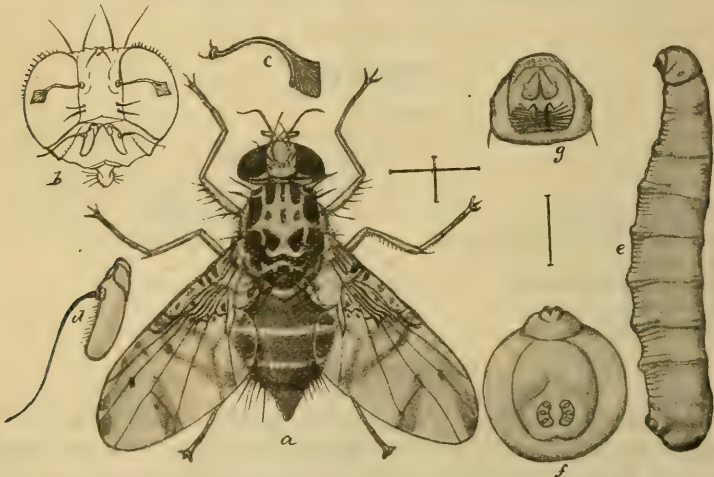


FIG. 1.—The Mediterranean fruit fly (*Ceratitidis capitata*): a, Adult female; b, head of same from front; c, spatula-like hair from face of male; d, antenna; e, larva; f, anal segment of same; g, head of same. a and e, Enlarged; b, g, f, greatly enlarged; c, d, still more greatly enlarged. (Howard.)

COMMON NAMES.

The common name "Mediterranean fruit fly" was first used by Frogatt in 1899 to distinguish *Ceratitidis capitata* from other fruit flies found in Australia. At the present time this name is the most widely used and most satisfactory of the common names by which this pest has been known and will be used by the writers. Other common names found in literature are "the fruit fly," "the maggot," "peach fly," "peach maggot," "fruit grub," "apricot worm," "trypeta fly," "West Australian fruit fly," "orange fly," and "orange fly trypeta."

ORIGIN.

Although Wiedemann first described *Ceratitidis capitata* from specimens collected by Daldorf, supposedly in the East Indies, the failure of subsequent entomological exploration in the Indo-Malayan region to

locate this species, except where it is known beyond question to have been introduced, has led entomologists to seek its original home elsewhere. Known facts concerning the artificial spread of this pest narrow its probable origin to the African continental area. According to Bezzi, the genus *Ceratitis* is of African origin. Information gained by various writers indicates that southern Europe is not its native home, although it has been recorded from this region for many years. Leonardi states that the Mediterranean fruit fly was not recorded as a pest in southern Italy until 1863, nor in Sicily until 1878. Had it been a native of Italy its ravages, as were those of the olive fruit fly (*Dacus oleae* Rossi), would have attracted the attention of writers prior to this time. While De Brême first records specimens reared in southern Spain in 1842, it is easier, in the light of more recent investigation, to believe Spain to be an adopted rather than the original home. Compere states that in 1903 there was living at Carcagente, Valencia County, Spain, an aged priest who could well remember the time in his childhood that peaches in that part of Spain were free from fruit-fly attack. Compere is also authority for the statement that commission merchants at Seville found that the pest was spreading farther inland to the north every season, even as late as 1903. The work of Graham (1910) and Silvestri (1912) has proved that *C. capitata* is present in the little-developed West African countries of Nigeria, Dahomey, and the Kongo, and Gowdy found the species already established in Uganda as early in the development of that country as 1909. These records, coupled with the information by the South African entomologists regarding its spread into the southern part of the African Continent, lend color to the statement of Silvestri that the natural habitat of *Ceratitis capitata* is "certainly tropical Africa south of 8° N. latitude." Silvestri, however, is of the opinion that one can not state whether the whole of this region should be considered as the natural habitat, or only the western portion, until careful studies have been made in French Equatorial Africa and British East Africa. Further exploration of the west coast of Africa north of 8° north latitude is very likely to establish new records of distribution and extend somewhat these limits of origin to include more semitropical territory.

DISTRIBUTION.

The Mediterranean fruit fly is at present established on every continent except that of North America. It has been recorded from the following regions:

Europe: Spain, France, southern Italy, Sicily, Greece, and Malta.

Asia: Asiatic Turkey (Beirut, Jerusalem, Jaffa.)

Africa: Egypt (Cairo and Kafir el Zayet), Tunis, Algeria, the Azores, Madeira Islands, Canary Islands, Cape Verde Islands, Dahomey, southern Nigeria, the Kongo, Cape Colony, Natal, Delagoa Bay, southern Rhodesia, British East Africa, Uganda Protectorate, Mauritius, and Madagascar.

Australasia: Western Australia, New South Wales, Victoria, and Queensland, northern New Zealand, and Tasmania.

South America: Brazil and Argentina (Buenos Aires).

North America: Bermuda Islands.

Hawaiian Islands.

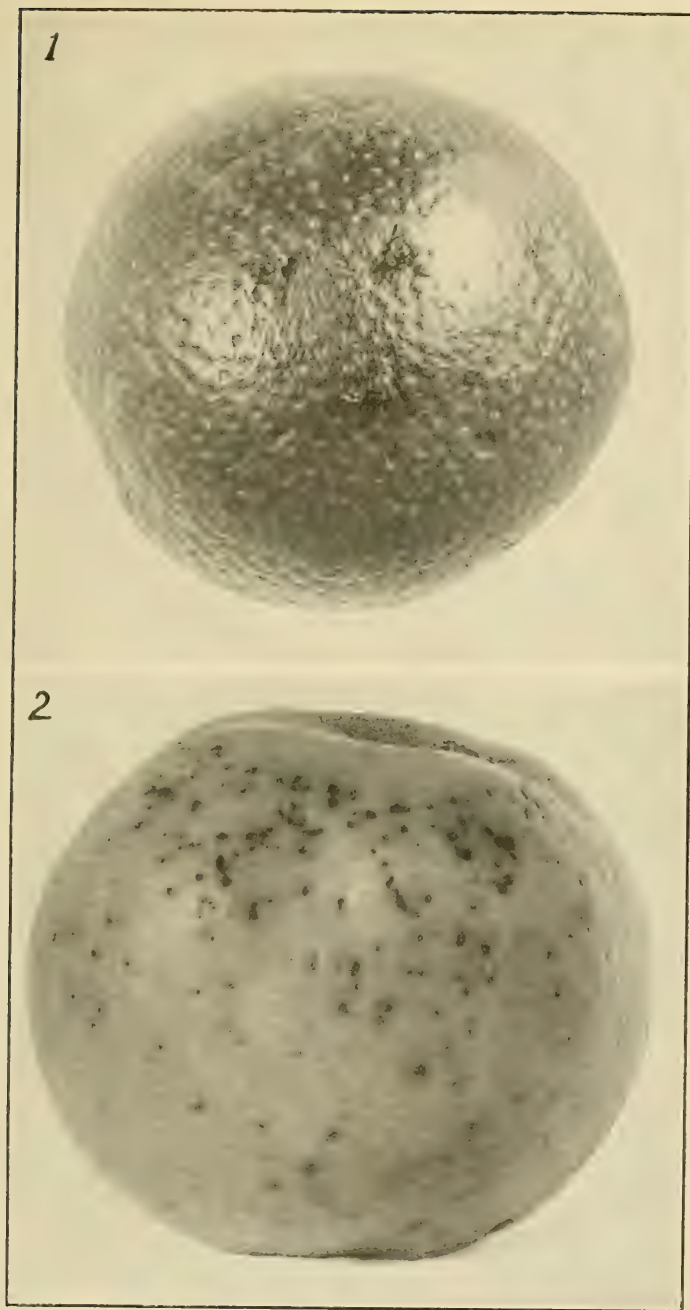
MEDITERRANEAN REGIONS.

The dates of the first discovery of the Mediterranean fruit fly in the countries bordering on the Mediterranean can not be used with precision in establishing a chronology of dispersion, since the pest may have been present many years prior to the first entomological observations recorded unless statements to the contrary are made in literature. Aside from our first record of establishment in Mauritius by Latreille in 1817, the earlier records refer to damage in the Mediterranean region. According to MacLeay this pest was well established in the Azores, Cape Verde, and Madeira Islands as early as 1829, and was the source of much injury to oranges arriving at London from these islands. It was first recorded from Spain in 1842, from Algeria in 1859, and from Tunis in 1885. Compere gives us our first records of its presence in Egypt at Port Said and in Asiatic Turkey at Beirut, Jaffa, and Jerusalem in 1904. During the same year, Cartwright records the infestation of oranges at Kafir el Zayet (Egypt) and four years later Froggatt found many infested oranges in the Cairo (Egypt) markets. Literature does not record the presence of this pest in Malta until 1890, although it was known to have become established there about 1875. In France the Mediterranean fruit fly was reared from apricots at Courbevoie, in the environs of Paris, in 1900, and by 1904 the fruit industry around Maritimes was ruined, according to Hooper. In 1916 the citrus crops in Attica (Greece) and Epirus (Southern Albania) were reported infested.

AFRICA.

Very little is known regarding the general distribution of the Mediterranean fruit fly throughout the great central portion of the African continent. While it is known to be a serious pest along the Mediterranean shores and to have spread into the southern portion, too few entomological observations have been made to warrant statements concerning spread throughout the more tropical regions. Graham in 1910 and Silvestri in 1913 state that it occurs in Dahomey, southern Nigeria, and the Kongo. Gowdey's records from Uganda in 1909 are the first from tropical East Africa, although Anderson states in 1914 that he had found *C. capitata* infesting coffee cherries in British East Africa. In 1912 Jack lists *C. capitata* as abundant throughout southern Rhodesia, but Morstatt states definitely that the pest did not occur in coffee cherries in German East Africa during 1913 and 1914.

The first record of injury caused by the Mediterranean fruit fly in South Africa was made by Miss Ormerod in 1889; but, as Mally states



THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Three adults of the Mediterranean fruit fly (*Ceratitis capitata*) about natural size, attempting to oviposit in an orange; note the relative size of flies and fruit. FIG. 2.—Ripe apple showing many punctures in the skin made by *C. capitata* in confinement. (Original.)

in 1904, it was introduced many years before. In 1893 Bairstow writes that he was familiar with *C. capitata* in South Africa in 1880, and that the Rt. Rev. Bishop Richards remembered damage done as far in the past as 40 years. In 1903-4 Fuller records *C. capitata* as one of the newly observed pests among the Natal orchards. It is not known whether the introduction in South Africa was by infested fruit from the Madeiras or by the gradual spread overland along the coastal regions, although the Madeiras seem the more probable source.

C. capitata was first recorded from Madagascar during 1914, when it was found seriously injuring the peach crop.

AUSTRALASIA.

Western Australia.—The Mediterranean fruit fly was first recorded in literature as a pest in Australia in 1897 by Fuller, who states that it had been known to have been established in western Australia for about two years in Claremont and Perth and along the Swan River, especially at Guildford. According to Despeissis, the first report of injury in Australia was made to the Bureau of Western Australia in 1894, which was, in his opinion, about one or two years after the date of its actual introduction. The pest has since been recorded from as far north as Geraldton and Northampton and as far south as Bunbury.

New South Wales.—In New South Wales the Mediterranean fruit fly was first reared in 1898. French found that peaches imported into Victoria from Sydney were infested and notified Froggatt. Within a few days Froggatt was able to verify this record by rearings of his own from fruit supposed to have been infested by the Queensland fruit fly (*Bactrocera tryoni* Froggatt). As Froggatt had been on the watch for *C. capitata*, it is probable that it became established about Sydney during 1898, although Rose, in 1897, states that in the northern part of New South Wales, at Warialda, peaches and nectarines had been nearly all destroyed in 1897 by a fruit fly first appearing about 1895 and identified by Froggatt as probably *C. capitata*. According to Froggatt, the pest has spread throughout all the citrus orchards of New South Wales to a greater or less extent.

Victoria.—Editorial comment in 1907 states that serious infestation of *C. capitata* had been recently discovered in the orchards in Goulburn Valley and farther west at Bendigo and at Horsham, and Froggatt is authority for its establishment at Albury and for the statement that it is present throughout the northern half of Victoria.

Queensland.—There are very few references to the presence of *C. capitata* in Queensland. Froggatt states, in 1909, that for a long time it was believed that it was not to be found in this part of Australia, but that, while it might not be abundant, he had specimens

from Brisbane. Voller, in 1903, mentions Brisbane, Toowoomba, and Warwick as places especially subject to *C. capitata* attack.

Tasmania.—The Mediterranean fruit fly became established in Tasmania about Launceston during the early part of 1899 and, according to Lea, attacked apples, pears, and peaches. As the result of a meeting of the Tasmania Council of Agriculture, held on June 1, to discuss correspondence regarding establishment and methods of eradication, a vigorous clean-culture campaign was authorized, which apparently was responsible for the eradication of the pest. No cases of infestation have since been observed in Tasmania fruit.

New Zealand.—Kirk states in 1901 that the Mediterranean fruit fly had not, up to that time, appeared in any New Zealand fruit-growing district. Two outbreaks were later recorded, at Blenheim and at Napier, respectively, but were reported to have been quickly stamped out by the destruction of the fruit and treatment of the soil. A third instance of temporary establishment in New Zealand was recorded in 1908 at Davenport. At present the Mediterranean fruit fly is not known to exist in New Zealand.

Islands about Australia.—In 1904 Kirk states that he had never reared *C. capitata* from fruits received in New Zealand from the islands of Suva, Nukualofa, Vavau, Rarotonga, Mangaia, Heratine, and Samoa.

BERMUDA ISLANDS.

The Mediterranean fruit fly was not recorded from the Bermuda Islands until 1890, when specimens of infested peaches were sent Dr. C. V. Riley. It was known as a pest in Bermuda during the 25 years previous, and is supposed to have become established about 1865, when a vessel carrying a cargo of fruit from the Mediterranean region, bound for New York, was forced by severe storms to discharge her cargo in Bermuda.

WEST INDIES.

There are no known records of the presence of *Ceratitis capitata* in the West Indies. The fact that the Jamaica Botanical Department in 1900 published a bulletin on orange culture and diseases, by Borg, in which reference is made to *C. capitata* as a pest of the orange, has led some to believe that the Mediterranean fruit fly has become established in Jamaica. The subject-matter of this bulletin was originally presented before the Malta Archeological and Scientific Society and contains nothing to warrant the conclusion that the author was dealing with the subject except in a most general way, particularly as he speaks of the fly occurring only about the Mediterranean.

Ballou, in an article published in 1913 on the prevalence of some pests and diseases in the West Indies during 1912, states that "fruit-fly" attacks were not so general in Dominica as in former years. The editor of the Review of Applied Entomology erroneously iden-

tified the "fruit fly" as "*C. capitata*." Ballou has since denied in correspondence that *C. capitata* was the insect in question.

SOUTH AMERICA.

Dr. L. O. Howard first identified the Mediterranean fruit fly from South America from specimens reared from peaches sent him by Dr. H. von Ihering in 1901. Compere, in 1904, and Lounsbury, in 1905, found the pest in the States of Sao Paulo and Rio de Janeiro. In 1906 Hempel states that *C. capitata* was the most common of the fruit flies attacking peaches in Sao Paulo.

In writing of fruit culture in Argentina in 1905, Lounsbury states that peaches near Buenos Aires were badly affected by an undetermined species of fruit fly which he thought likely to be *Ceratitis capitata*. Silvestri definitely records *C. capitata* from Buenos Aires, presumably as a result of this statement of Lounsbury.

HAWAIIAN ISLANDS.

The Mediterranean fruit fly was first observed in the Hawaiian Islands by Mr. D. T. Fullaway, who captured a living adult in the insectary at the U. S. Department of Agriculture Experiment Station on June 21, 1910. During the following September another adult was captured by Terry and Perkins on the laboratory windows of the Hawaiian Sugar Planters' Association. Observations made in the field during September by Terry showed that the pest was already established in the Punchbowl district of Honolulu on oranges and limes, and from that time new records of infestation were rapidly brought to light. By October, 1911, the pest had already become established on the island of Kauai, and was known to exist on Molokai at least by January, 1912, when it was first recorded from the Kohala district of the island of Hawaii. During March, 1912, specimens of infested coffee cherries were reported from the Kona district of Hawaii. The first records of establishment in the Puna district of Hawaii were made during March, 1913, when infested oranges and peaches were found at Naalehu and Hilea. Peaches were not reported infested in the Hilo district of Hawaii until the spring of 1914, but soon after infestations were found throughout the Hilo and Hamakua districts. The fruit fly was found established on the Island of Maui by May, 1912. By July, 1914, the Mediterranean fruit fly had spread to every important island of the Hawaiian group, and at present is well established in every village and wild guava scrub examined by the writers. Judging from the rapidity with which this pest has spread throughout new districts in Hawaii, the writers agree with Ehrhorn that the pest secured its first foothold in Hawaii at Honolulu about 1907, although there are several well-informed horticulturists in Honolulu who believe establishment occurred even one or two years earlier.

SOURCE OF HAWAIIAN INFESTATION.

There is little doubt that the Mediterranean fruit fly was carried to the Hawaiian Islands from Australia on one or more of the ships



FIG. 2.—Map of the Hawaiian Islands, showing their relative position and their relation to one another in the distribution of the Mediterranean fruit fly.

plying between the ports of these two countries. Before this fruit fly was known to have become established about Honolulu, Compere, as a traveler between Australia and Honolulu, observed *C. capitata* larvæ emerging from host fruits stored on the deck of his vessel and

pupating in the corners of the fruit containers and in secluded spots about the deck. It would have been quite possible for larvæ thus emerging to have completed their development during the days required for the voyage between Sydney and Honolulu and emerged as adults while the ship lay at anchor at Honolulu within several hundred yards of host fruit trees. As the Mediterranean fruit fly did not become established about Sydney and the eastern portion of Australia until 1898-1907, its establishment about Honolulu between 1907 and 1908 came as a natural sequence. This is most forcibly brought to the attention of those interested in horticultural development when they appreciate the frequency with which this pest has attempted to bridge the Pacific between Honolulu and San Francisco since its establishment at Honolulu, as indicated by the interception of infested fruit at San Francisco by officers of the Federal Horticultural Board.

CONDITIONS FAVORABLE TO ESTABLISHMENT IN THE HAWAIIAN ISLANDS.

CLIMATIC CONDITIONS IN HONOLULU.

The climate of the littoral regions of Hawaii, and up to an elevation of 1,500 feet, is most favorable to the establishment and rapid increase of *C. capitata*. At Honolulu the temperature very rarely drops as low as 58° F., and then only for a few hours during one or two nights in the year. The data in Table I, taken from the monthly meteorological summaries of the U. S. Weather Bureau at Honolulu for 1914, are given as a fairly reliable guide to the ranges in temperature throughout littoral Hawaii.

TABLE I.—*Temperature and relative humidity at Honolulu during 1914.*

Month.	Temperature.									Relative humidity.		
	Maxi- mum.	Mini- mum.	Daily range.			Mean at ¹			Mean of maxi- mum and mini- mum.	Maxi- mum.	Mini- mum.	Mean.
			Maxi- mum.	Mini- mum.	Aver- age.	6 a. m.	2 p. m.	9 p. m.				
January.....	° F. 78	° F. 60	° F. 18	° F. 6	° F. 10	° F. 67.4	° F. 74.0	° F. 68.9	° F. 69.1	P. ct. 83	P. ct. 50	P. ct. 66.4
February.....	81	61	14	8	11.4	66.2	72.4	68.3	71.4	82	52	70.9
March.....	80	57	15	7	10.5	67.5	74.8	69.6	70.9	86	53	68.6
April.....	82	60	15	7	10.7	68.6	75.8	70.9	72.5	81	52	68.7
May.....	83	66	14	6	9.4	72.6	79.9	74.6	74.3	82	56	70.1
June.....	83	69	12	6	9.1	74.0	80.4	76.0	76.6	80	58	68.8
July.....	85	70	15	6	9.2	75.2	81.5	76.3	78.4	81	62	69.6
August.....	86	71	12	5	9.1	76.0	81.4	76.8	79.0	80	58	69.2
September.....	87	70	12	6	8.1	75.9	80.6	77.0	78.7	85	62	71.4
October.....	83	67	14	7	9.4	73.6	79.7	75.1	77.0	74	60	68.0
November.....	83	65	13	5	10.2	71.4	77.2	72.9	74.6	85	52	70.5
December.....	80	61	14	7	10.7	67.6	74.3	69.7	71.1	89	60	72.7

¹ Compiled from 1914 and 1915 data, taken from the 1916 Hawaiian Annual.

² The normal mean for January is 71.1° F.

It will be observed that the daily range is very small, averaging between 8 and 11 degrees, and that the normal monthly mean temperatures range between 70.9° and 79° F. In Table II are given the monthly and yearly means, together with the yearly maximum and minimum temperatures, recorded at different places on the islands of Hawaii, Maui, and Oahu, which, at their respective elevations, represent the variations in range of temperature from that in Honolulu, to be found at points in Hawaii where host fruits are grown.

TABLE II.—*Monthly and annual mean and maximum and minimum temperatures of representative localities in Hawaii where host fruits of the Mediterranean fruit fly may be grown.*

Locality.	Elevation.	Monthly mean temperatures.														Annual.	
		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.	Highest temperature recorded.	Lowest temperature recorded.	
Island of Oahu:	<i>Feet.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	<i>° F.</i>	
Honolulu.....	111	70.0	69.7	71.4	73.3	74.3	75.3	76.4	78.1	76.8	75.2	74.7	72.4	74.0	85	58	
Waialua Mill.....	30	70.4	68.7	71.0	72.7	73.4	74.4	75.8	77.0	75.9	73.9	72.8	70.5	73.0	91	55	
Waianae.....	671	37.0	47.1	97.3	87.4	87.7	37.9	28.0	07.9	37.5	57.4	87.3	27.5	1	91	52	
Schofield Barracks.....	990	66.6	65.8	67.4	68.9	69.8	71.0	73.0	74.0	73.2	71.2	66.6	68.2	69.6	89	51	
Tantalus Heights.....	1,300	63.6	64.1	66.3	67.2	68.0	67.7	69.3	70.4	69.1	68.5	67.4	65.6	67.3	84	54	
Island of Maui:																	
Kaanapali.....	127	70.2	70.4	71.4	74.0	76.0	77.3	79.3	80.0	79.4	76.5	75.2	73.0	75.2	92	57	
Wailuku.....	250	68.8	69.2	69.8	72.2	73.0	74.1	75.5	77.4	75.8	74.0	72.8	70.9	72.8	89	56	
Haiku.....	700	67.2	67.2	68.6	69.6	70.7	70.7	72.8	74.2	72.4	71.8	70.4	68.7	70.4	83	57	
Island of Hawaii:																	
Hilo.....	100	68.4	68.7	69.4	70.8	71.3	72.4	74.0	74.6	73.8	73.0	71.4	69.6	71.4	88	55	
Honokaa.....	470	67.6	67.8	70.1	71.0	72.3	72.6	73.4	74.6	72.8	72.4	71.2	69.0	71.2	90	53	
Holualoa.....	1,350	67.0	66.6	66.7	68.8	68.3	69.4	70.8	71.2	70.8	69.4	68.2	66.6	68.6	84	51	
Huehue.....	2,000	65.2	65.4	66.4	68.3	68.6	70.1	72.6	73.3	71.7	69.8	68.8	66.8	68.9	87	50	
Pahala.....	850	68.6	68.4	68.7	71.2	71.2	72.1	74.0	75.2	74.9	73.0	72.4	70.7	71.8	91	53	
Kohala Mill.....	270	68.4	67.9	69.9	70.9	72.2	72.6	74.2	75.2	74.2	73.1	71.7	70.4	72.1	86	54	
Waimea.....	2,720	58.6	60.4	62.0	61.9	61.9	61.8	63.6	65.1	63.7	64.2	61.7	60.4	62.1	80	44	
Volcano House.....	4,000	57.8	58.6	59.0	59.6	59.2	60.1	60.0	59.2	59.3	61.0	60.8	60.4	59.6	72	42	

Biological work has shown that even the lowest monthly means of localities up to 1,500 feet elevation have little effect upon *C. capitata* other than to retard development somewhat. It is never cold enough throughout littoral Hawaii to render either the adults or the larvæ inactive. As a result there are no periods of the year at any Hawaiian port when the climatic conditions are unfavorable for the establishment or increase of this pest. Data presented later in the text indicate that a continuous temperature ranging between 58° and 62° F., or the lowest range of temperature usually experienced in littoral Hawaii, does not increase the normal mortality among the immature stages of the fruit fly, and that these stages withstand for short periods, without injury, temperatures lower than any recorded in Table II. The two stations, Holualoa and Huehue, at about 1,350 and 2,000 feet elevation, respectively, may be taken as fair examples of altitudes above which host fruits are only scatteringly grown, but at which the fruit fly has demonstrated its capacity to injure fruits seriously.

HOST CONDITIONS.

Favorable as are the climatic conditions for the establishment and increase of the Mediterranean fruit fly in Hawaii, the host conditions are even more so. Mr. H. J. Quayle, who has studied fruit-fly conditions throughout southern Europe, and Mr. J. C. Bridwell, who has had similar opportunities in western and southern Africa and in Australia, have stated to the writers that nowhere have they found host conditions so favorable for establishment and rapid increase as in littoral Hawaii, especially about Honolulu and Hilo. Under the subject of host fruits, on page 24, the writers record 72 species of fruits growing in Honolulu that are subject to attack by *C. capitata*. The discussion of their susceptibility to attack, however, throws little light upon their numerical abundance or upon the seasons of the year during which their fruit is available for fruit-fly infestation. During the clean-culture campaign waged against this pest in Honolulu during 1913, data were secured which forcibly demonstrate the ideal host conditions found in Honolulu, making possible extraordinary increase and excessive infestations. The residents of Honolulu are justly proud of their magnificent vegetation and have taken great pleasure in growing an unusually large assortment of trees and shrubs upon their town properties. An inventory of such trees and shrubs, that bear fruits subject to infestation, growing upon 60 blocks in that portion of Honolulu bounded by Liliha, Punchbowl, Beretania, and School streets, is given in Table III.

TABLE III.—*Number of host trees and shrubs of the Mediterranean fruit fly growing during 1913 in that portion of Honolulu bounded by Liliha, Punchbowl, Beretania, and School streets.*

Block.	Lots in block.	Trees in block.	Block.	Lots in block.	Trees in block.	Block.	Lots in block.	Trees in block.	Block.	Lots in block.	Trees in block.
1	19	81	16	18	90	31	7	19	46	9	160
2	10	64	17	6	13	32	10	62	47	4	51
3	10	105	18	5	20	33	5	10	48	15	217
4	3	0	19	23	101	34	5	22	49	23	167
5	16	137	20	12	48	35	5	9	50	6	111
6	9	28	21	18	118	36	8	51	51	16	112
7	9	64	22	7	59	37	14	134	52	9	41
8	4	59	23	3	0	38	13	108	53	5	65
9	6	18	24	14	75	39	41	115	54	14	83
10	9	124	25	3	8	40	12	74	55	23	112
11	28	132	26	7	25	41	36	135	56	26	158
12	6	163	27	4	7	42	17	76	57	12	37
13	9	66	28	4	15	43	18	208	58	4	0
14	9	66	29	9	42	44	24	144	59	3	124
15	25	86	30	2	39	45	9	54	60	12	98

Total number of lots in 60 blocks, 712; total number of trees, 4,610; average number of trees per lot, 6.5; average number of trees per block, 76.8.

From this it will be seen that there was a total of 4,610 trees and shrubs on the 712 lots under consideration, or an average of 6.5 trees per dooryard capable of supporting the fruit fly. In Table IV are given data indicating the relative abundance of different hosts.

TABLE IV.—Number and species of host trees of the Mediterranean fruit fly growing in that portion of Honolulu covered by Table III.

Apricot.....	1	Fig.....	201	Mandarin.....	28	Rose apple.....	25
Avocado.....	653	Guava, common..	94	Mango.....	1, 154	Sapodilla.....	5
Breadfruit.....	58	Guava, strawberry	73	Mangosteen.....	7	Sapota.....	30
Carambala.....	48	Java plum.....	80	Mountain apple.....	41	Soursop.....	57
Chinese inkberry..	4	Kamani, ball.....	4	Mock orange.....	33	Spanish cherry..	1
Chinese orange....	148	Kamani, winged..	13	Orange, sweet....	372	Star apple.....	4
Coffee.....	298	Kumquat.....	4	Papaya.....	687	Surinam cherry..	63
Coffee, Liberian...	8	Lemon.....	22	Peach.....	69	Wi.....	19
Cotton.....	11	Lichee.....	40	Pear, Bartlett....	2	Waiawai.....	60
Custard apple....	1	Lime.....	10	Pomegranate.....	128		
Damson plum.....	4	Loquat.....	33	Pomelo.....	15	Total.....	4, 610

In Hilo, island of Hawaii, host conditions are quite as favorable for fruit-fly development as in Honolulu. Thus the following numbers of host trees and shrubs were found in certain yards of Hilo during March, 1914:

YARD 1.	YARD 2.	YARD 3.	YARD 4.
1 Rose apple. ¹	2 Surinam cherry.	11 Rose apple.	4 Peach.
4 Surinam cherry.	2 Papaya.	2 Mango.	6 Mango.
2 Japanese plum	1 Thevetia.	3 Thevetia.	1 Loquat.
6 Mountain apple.	2 Orange.	1 Avocado.	3 Winged kamani.
1 Star apple.	2 Strawberry guava.		2 Surinam cherry.
34 Coffee trees.	14 Coffee.		1 Strawberry guava.
20 Common guava.	Bananas.		
15 Brazilian banana.	2 Avocado.		
4 Avocado.	1 Peach.		
3 Mango	3 Fig.		
2 Papaya.	2 Mountain apple.		
5 Orange	2 Lichee nut.		
1 Peach.	3 Common guava.		
1 Grape.			
1 Winged kamani.			
1 Mangosteen.			
1 Fig.			
1 Mimusops.			

There is no time in Hawaii when fruits are entirely out of season. The fact that several hosts, such as the Chinese orange (*Citrus japonica*), Surinam cherry (*Eugenia michelii*), and mock orange (*Murraya exotica*), bear several crops a year, while others, such as certain specimens of ball kamani (*Calophyllum inophyllum*) (Pl. VI) and winged kamani (*Terminalia catappa*) (Pl. XIX), appear to be seldom entirely free from ripening fruits, assures food for the fruit fly the year round.

The succession of fruits is also increased by the individuality of trees of the same species, or even of certain branches of a single tree, which results in a very uneven ripening of the fruit. While the data in Table V do not indicate the seasonal abundance of host fruits, they have been summarized from the collections of clean-culture inspectors made during 1913 to show the remarkable succession of host fruits found ripening in greater or less quantities throughout

¹ For scientific names of fruits see section on host fruits, p. 24.



RELATION OF FLORA OF HAWAIIAN ISLANDS TO THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Men grubbing out a guava scrub which has taken possession of pasture land. Many thousands of acres are thus overrun in Hawaii and furnish excellent breeding grounds for the fruit fly. The ripening fruits fall into the dense grass and the larvæ within them develop unmolested by the heat of the sun. FIG. 2.—Thickets of guava bushes often crowd upon the country roads and ripen tons of fruit. This fruit is gathered by pedestrians and autoists and carried to all parts of the islands, thus becoming a medium for the wide dissemination of the pest. (Original.)



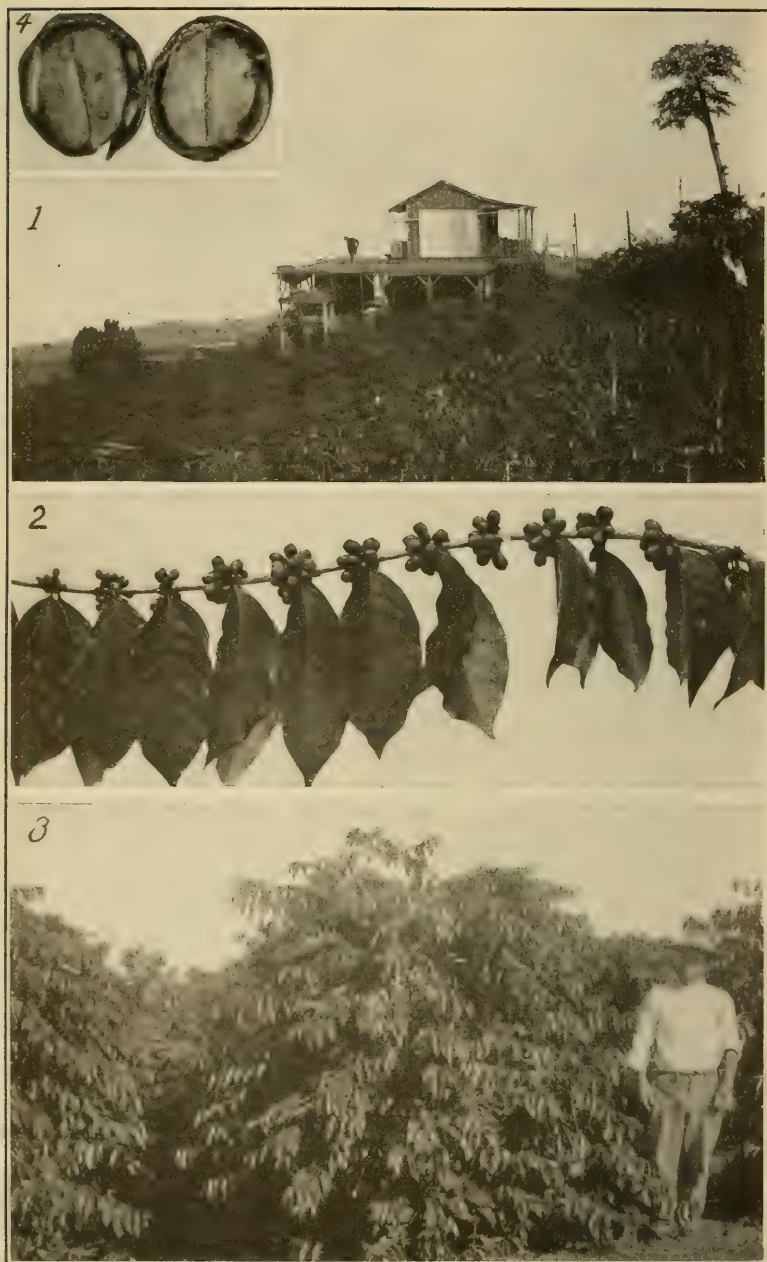
RELATION OF THE FLORA OF THE HAWAIIAN ISLANDS TO THE MEDITERRANEAN FRUIT FLY.

It is difficult to find in Hawaii cultivated fields of any crop that are not closely surrounded by wild hosts of the fruit fly. In the above illustration, between the pineapple field in the foreground and the ocean, are growing, at the right and left, dense thickets of guava, while in the center are many large Terminalia trees. In such places the fruit fly finds, in the ripening fruits of these hosts, food for its support throughout the entire year. Throughout the precipitous and gullied mountains in the background the fruit fly is thoroughly entrenched in wild host fruits. (Original.)



THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—A dense forest growth of the mountain apple (*Jambosa malaccensis*) near Hilo, which illustrates one of the many strongholds in Hawaï that the fruit fly found favorable to its thorough entrenchment. FIG. 2.—Rose apple trees (*Eugenia jambos*). While the fruit of this tree ripens chiefly during the months of March to May, a few may be found beneath trees at any time. Fruits of both the mountain apple and the rose apple are among a class of host fruits that are carelessly taken on board ships by tourists, in whose possession they have been intercepted by the officers of the Federal Horticultural Board at San Francisco. (Original.)



THE MEDITERRANEAN FRUIT FLY AND THE COFFEE INDUSTRY.

FIG. 1.—Coffee plantation on the Kona slopes of Hawaii. FIG. 2.—A fruiting branch. FIG. 3.—Low type of coffee tree. FIG. 4.—Coffee cherry cut to show the two large beans which are of commercial value, and the very thin outer pulp. This pulp is the only portion of the cherry eaten by the fruit-fly larvæ. Note that the well-grown larvæ illustrated feed so close to the papery epidermis that parasites have no difficulty in ovipositing in them. Thousands of acres are densely planted to coffee on the island of Hawaii and offer food for the fruit fly the year round. (Original.)

the year in Honolulu. The presence of so much ripening fruit, coupled with the favorable climatic conditions and the hardness of the fruit fly itself, has made the establishment of *C. capitata* and its multiplication a most easy problem within the city limits.

While the fruit fly finds host conditions most favorable within the city limits, because of the large number of host trees and shrubs, some of which are bearing at all seasons of the year, it has been able to establish itself and multiply in the country, often miles from towns, in some one or more of its hosts which have escaped cultivation, and to have spread over uncultivated and uncultivable areas. Of such hosts, the common guava (*Psidium guayava*) is the most abundant. It has taken possession of the roadsides, pastures (Pl. II), vacant town lots, mountain gulches and hillsides, and even crevices in precipices, from sea level up to 1,500 feet elevation.¹ So easily does this plant grow from seed, and so thoroughly distributed are its seeds by cattle, birds, and man, that it is seldom that a bush can not be found within a stone's throw. In the lowland pastures and mountain gulches up to an elevation of at least 1,300 feet, particularly when sheltered from strong winds and well watered, the guava may become very treelike and form dense thickets (Pl. III). At higher altitudes, and in wind-swept or arid areas, it may remain a low, scrubby bush. While the guava fruits most heavily during the spring and fall months, the bushes are continually blooming and ripening a sufficient number of fruits to support the fruit fly every month in the year. The writers are depending upon the illustrations to acquaint the reader, as words can not, with the well-nigh universal distribution of this host and the wonderful opportunities it offers *C. capitata* for easy establishment and thorough intrenchment.

Second to the guava as a host occurring in wild, uncultivated areas is the prickly-pear cactus (*Opuntia vulgaris*) (Pl. XVII). While the fruits of this plant are not preferred by the Mediterranean fruit fly, they are sufficiently infested in the absence of more favored hosts to serve as food, and, as in the case of the guava, there is almost no time during the year when a few ripe fruits may not be found in any cactus scrub.

Other host fruits, wild or escaped, are not so universally distributed. As a few of the many examples, there may be mentioned a grove of ball kamani trees in an isolated valley on the island of Molokai, gulches overgrown with the passion vine (*Passiflora* sp.) and the damson plum (*Chrysophyllum oliviforme*) on the island of Maui, the thickets of winged kamani growing along the windward shores of the island of Oahu, and the wild coffee and mountain apple (Pl. IV, fig. 1) in the forests of Oahu and Hawaii.

¹ Stunted bushes have been observed at 4,000 feet elevation.

In addition to the wild fruits in country places, the fruit fly finds strongholds in the many, and often very isolated, native-home sites scattered throughout the littoral regions. About these may be growing the mango (Pl. XII), rose apple (Pl. IV, fig. 2), orange, peach, avocado, ball and winged kamanis, etc. In the Kona district of the island of Hawaii there are large areas containing thousands of acres of coffee under cultivation (Pl. V) in which the fruit fly finds food in the pulp of the ripening cherries at all seasons of the year because of the irregularity in blooming and the long harvesting season due to the varying altitudes at which coffee is grown.

ECONOMIC IMPORTANCE.

The economic importance of the Mediterranean fruit fly as a pest of fruits varies with the climate of its habitat. Thus in France, near Paris, where it has been known to attack apricots, pears, and peaches, it has not become a serious pest because of climatic checks, and such checks to the severity of its attack have been noted in portions of Australia and South Africa and would be operative in continental United States, except in parts of California and of the Southern States. On the other hand, in tropical and semitropical climates this fruit fly is capable of becoming a pest of prime importance and, as in the Hawaiian Islands, may be classed as the most important insect check to horticultural development. A study of the fruits infested by this world-wide pest shows that practically every fruit crop of value to man is subject to attack. Not only is the Mediterranean fruit fly of importance as a destroyer of fruit, but it is the cause of numerous stringent quarantines which cost the State and Federal governments much money to make effective, and rob countries of good or prospective markets for their fruit. Fortunately it has been found that the Chinese banana (*Musa cavendishii*) and the pineapple (*Ananas sativus*), the two most valuable species of fresh fruits formerly exported from Hawaii, offer so little danger as carriers of the Mediterranean fruit fly when they are packed for shipment that this part of Hawaii's export trade with the coast may still be carried on, provided the inspections of the Federal Horticultural Board now in force are continued. The necessary quarantine against all other host fruits, however, particularly against such fruits as the avocado and mango, two fruits which can be grown very well in Hawaii, has had, and will continue to have, a serious effect upon horticultural pursuits and the development of the small farmer.

At the present time the infestation of edible fruits in littoral Hawaii is general and about as severe as could be expected. Aided by the melon fly (*Bactrocera cucurbitae* Coq.), the Mediterranean fruit fly has effected a most serious and permanent check upon the horticultural development of the Hawaiian Islands unless a successful

method for combating it is developed. In the Bermuda Islands the peach industry has been a ruined one for many years. MacLeay and Westwood wrote, during the early part of the nineteenth century, of the increased cost to the inhabitants of London of citrus fruits imported from the Azores as a result of fruit-fly attack. Lounsbury and Mally, of South Africa, consider *C. capitata* one of the greatest drawbacks to the development of the fruit industry in Cape Colony, and have stated that during certain favorable seasons large areas of apricots, figs, pears, plums, apples, and quinces were almost all affected. Hooper, writing from Southern France, states in 1904 that, as a result of fruit-fly attack, what was once an important and lucrative industry was at that time little more than a haphazard traffic in fruit casually produced. In 1903 Compere found that peach growing about Barcelona, Spain, had been so demoralized by fruit-fly attack that few trees were being grown and that the market was supplied by fruit from the Balearic Islands, while at Cadiz the fruit merchants no longer cared to handle peaches owing to the fact that they were badly infested. At Malaga, according to Compere, the bitter Seville oranges are seriously affected. Wickens, writing in 1913 in Western Australia, states that the fruit industry there was suffering not only directly as a result of the actual loss of fruit infested, but indirectly through the restricted plantings in districts where the fruit fly was abundant. About Perth, where late peaches can be grown to perfection, very few are being cultivated; instead, many trees have been cut down. Other instances of damage caused to citrus crops in southern Europe, South America, Africa, and Australia might be added which would impress one, unfamiliar with the ravages of *C. capitata*, that it is a very serious pest. Its economic importance is so great that every effort should be taken to prevent its establishment in new territory.

INJURY.

NATURE OF INJURY.

The injury caused by the Mediterranean fruit fly is confined to the fruits of the hosts attacked. The foliage, stems, and roots are not attacked so far as investigators have been able to determine. No better idea of the nature of the injury caused by the fruit fly can be gained than from an examination of the illustrations. The larvæ hatching from the eggs deposited just beneath the epidermis burrow their way throughout the pulp and, as they develop, cause by their feeding, and through the development of fungi and bacteria, decayed areas which vary in extent according to the age and number of the larvæ and the ripeness of the host. Since the larvæ most frequently burrow at once to the pit or core of the fruit, they are able to feed for some time before their work is evident from the surface; thus peaches and

oranges may be quite thoroughly devoured within and yet maintain a fairly normal appearance externally. In rapidly growing fruits, or those oviposited in while they are still too green to support larval growth, slight deformities are developed which injure the appearance of the fruit. In lemons, oranges, and grapefruit which have been provided so well by nature to withstand fruit-fly attack, the rind may become badly infested with eggs and young larvæ, while the pulp remains edible. The breaks in the skin made by the female fly in depositing eggs, however, affect the shipping qualities of such citrus fruits and, from this commercial aspect, may cause an injury the nature of which is quite as serious as is any to the pulp.

EXTERNAL EVIDENCES OF INJURY.

There are always external evidences of infestation, but these are often so inconspicuous that they are overlooked by the average person. The eggs are deposited by the adult through a break, no larger than a pin prick, made in the skin. While these punctures are readily discernible under the hand lens as soon as made, there is nothing about them to attract attention. Soon after oviposition, however, the tissues about the egg cavity begin to wither and there develops about the puncture a discolored or sunken area in the skin. In certain hosts the immediate area about the puncture may remain green long after the remainder of the fruit has turned yellow, as in the loquat (*Eriobotrya japonica*), or red, as in the strawberry guava (*Psidium cattleyanum*). In green oranges the fruit may turn yellow about the puncture while the rest of the fruit remains green. Such tender-fleshed fruits as the ripening Surinam cherry (*Eugenia michelii*) may develop sunken areas without discolorations. Often filaments of clear gummy excretions exude from punctures made in peaches, lemons, and grapefruit. Punctures made in green star apples (*Chrysophyllum cainito*) are usually marked by exuding white latex which dries about and over the puncture. Punctures made in quite green winged kamani nuts (*Terminalia catappa*), in which no development of larvæ occurs, are marked by depressions in the flesh due to permanently arrested development at the punctured point. Oviposition or attempted oviposition in bananas and partially ripe mangoes is followed by exudations which run down the sides of the fruit and dry as a dark stain. The evidences of early infestation such as have just been mentioned are too numerous to warrant description. No one host responds to infestation exactly the same each time; much depends on the degree of ripeness at the time of attack. There may be no gummy exudations from peaches or citrus fruits, and there may be no development of discolored areas in any of the host fruits. Avocados seldom give evidence of infestation by any external mark except the puncture in the skin. Fruits already

ripened when infested show none of the usual signs of attack until the larvæ have begun to work. It is due to this failure of fruits to record their infestation by some external sign, other than the inconspicuous puncture, that so much fruit is purchased as sound in the markets, or shipped from orchards, or taken on board ships.

As the larvæ hatch and begin their work of destruction within the host, the signs of infestation increase rapidly. The sunken areas about the punctures of tender-fleshed fruits may increase until the entire fruit has a collapsed appearance.

In all fruits well infested within there is a "give" to the area beneath the puncture, indicating destroyed tissues beneath. In hard-fleshed fruits such as some varieties of apples (Pl. XI, fig. 2), pears, and quinces there may be no external evidence of larval work except a ring of dark decay about the puncture, and yet the outer portion of the pulp alone may be unaffected. Peaches are often thoroughly infested within and still maintain their normal shape and give evidence of infestation only by a dull and slightly darkened color of the skin. A hole in the rind, no larger than the lead of a pencil, from which juice exudes when the fruit is compressed, may be the only indication of infestation in oranges and grapefruit, although rings of decay usually develop in infested citrus fruits containing numerous larvæ. Fruits of the elengi tree (*Mimusops elengi*), which have an orange shell-like exterior (Pl. VIII, fig. 2), may appear normal, but on being broken open are found to be literally packed with well-grown larvæ. It is never possible for the average man to examine casually any host fruit and state conclusively that it is not infested.

METHODS OF SPREAD.

There are numerous records on file which demonstrate clearly the methods by which the Mediterranean fruit fly is spread, not only between widely separated countries, but about land areas. The development of rapid transit and cold storage and the increase in tourist travel have been the greatest factors in dissemination in more recent times. Geographical isolation is no longer a protection against introduction, as has been proved almost monthly by the interception of fruit flies at the ports of entry of the United States by the agents of the Federal Horticultural Board.

SHIPS.

The unrestricted consignments of fruit and ships' stores have been responsible for much of the spread of *C. capitata* between countries. MacLeay, as early as 1829, records the importation at London of cargoes of oranges from the Azores that contained larvæ, and Middleton, in 1914, states that in the same city hundreds of larvæ and pupæ are imported every year from Spain and destroyed

in the manufacture of marmalade. The establishment of *C. capitata* in both the eastern and western parts of the Australian continent is traceable to the development of cold storage and rapid ocean transportation which made possible the large exports of citrus fruits from the Mediterranean region to Australia. Kirk records the receipt at Auckland, New Zealand, of a case of peaches from Cape Colony which contained living larvæ, although they had been en route in cool storage for four weeks. The same writer intercepted 47 cases of infested apples at Wellington, New Zealand, imported from New South Wales. Lea, in 1908, states that larvæ of *C. capitata* were seen in numbers every year in fruit imported into Tasmania from Sydney. The establishment of this pest in the Bermudas and South America is beyond doubt the result of the importation of infested fruit from Mediterranean regions. Increased knowledge of fruit flies and the quarantines in force in several countries now make the introduction of this pest in consignments of fruits less likely.

The vigilant work of the quarantine officials at the Pacific ports of the United States, however, demonstrates the grave danger that still exists of introducing the Mediterranean fruit fly in ships' stores. Instances of the discovery and destruction of the pest in fruits in ships' stores on vessels entering the port of San Francisco during the past four years are recorded in the reports of Frederick Maskew, chief quarantine officer of the California Horticultural Commission and collaborator of the Federal Horticultural Board.

TOURISTS.

The desire on the part of tourists to carry to their friends at home specimens of exotic fruits is at the present time the most likely avenue for the introduction of this fruit fly into California as well as the southern United States. This has been clearly proved not only by the large variety of host fruits offered for inspection at Honolulu, but by the interceptions at the California ports. To the quarantine officer the tourist is a difficult problem. Fruits carried in containers are easily observed, but smaller fruits are found with difficulty. Strong, in 1913, discovered in the overcoat pocket of a tourist landing at San Francisco infested nuts of the winged kamani (*Terminalia catappa*), which were intended for planting in southern California. In like manner infested coffee cherries were found at Honolulu in the pocket of a gentleman about to sail during February, 1916, from Honolulu direct to San Pedro, Cal.

DISSEMINATION ON LAND BY PUBLIC AND PRIVATE CONVEYANCES.

On land, railroads, automobiles, hawkers' carts, carriages, etc., are all responsible for much spread. The fact that host fruits only slightly infested appear normal to the average man leads to the pur-

chase by the traveling public of much fruit which later, when found to be infested, is discarded, often many miles from the point of origin. Bairstow as long ago as 1893 records the selling of infested apricots by native girls to passengers on trains about to leave for interior points of South Africa. The spread of the pest in Australia has been most rapid along the railroads. French, in 1896, states that peaches imported by rail into Victoria from Sydney were infested and Newman states that in Western Australia many instances have come under his observation in which infested fruits thrown from the windows of coaches of both suburban and country trains were responsible for introductions into districts previously free from attack.

In the Hawaiian Islands the spread from village to village and from island to island unquestionably has been hastened by the habit of the poorer population of carrying small lots of fruit in their travels, either for food while en route or as presents for their friends. Much of this fruit is more or less infested, and when an attempt to eat it proves the interior to be infested and unpalatable, it is discarded either along the road or at the point of destination. The inspection service of the Hawaiian Board of Agriculture has shown that even the most stringent regulations have not prevented the movement of infested fruits from point to point by man in automobiles, in carriages, or on foot.

POSTAL AND EXPRESS PACKAGES.

The interception at Washington, D. C., by officers of the Federal Horticultural Board of a package from Mexico containing a living pupa of the papaya fruit fly (*Toxotrypana curvicauda* Gerst.) attached to an unknown vine, and of a living adult of the olive fruit fly (*Dacus oleae* Rossi) and a dead adult of another species of fruit fly, apparently *Dacus semispharens* Becker, in a package of olive seed, 28 days after it had been mailed in South Africa, indicates the possibilities for spread by means of parcel post. The persistency with which uninformed persons insist upon including among bananas and pineapples intended for shipment by express from Hawaii to the mainland United States small contraband host fruits has demonstrated fully the danger of express packages as carriers of *C. capitata*.

NURSERY STOCK.

A fruit-fly pupa (species unknown) was found at Auckland, New Zealand, in the soil about the roots of a plant imported from Australia. Newman has called attention to the danger of spreading the fruit fly in the pupa stage, in the soil about the roots of nursery stock grown beneath host fruit trees.

PACKING MATERIALS.

Larvæ developing in fruits packed in wooden crates or in bags often pupate against the sides of such containers. Second-hand

packing crates and old burlap, etc., recently used as containers are apt to carry the pest and should be guarded against until experience for the locality and temperature concerned has proved that the adults have emerged. Certain instances of spread in western Australia are believed to have occurred through carelessness in the use of second-hand packing cases. In Hawaii, Hilo grass (*Paspalum conjugatum*), gathered from beneath guava bushes (Pl. XIV, fig. 1, insert), was discontinued as a packing material for bananas for fear pupæ of the fruit fly attached to it might reach California.

COLD STORAGE.

While cold-storage temperatures may be used to render fruits free from danger as transporters of the fruit fly (see p. 108), the use of temperatures fluctuating above 38° F. may be one of the greatest aids in prolonging the duration of fruit-fly life within host fruits.

WIND.

That adult males of the Mediterranean fruit fly can be carried by the wind distances varying from one-fourth to 1½ miles from points of liberation has been demonstrated by Severin, who states further that in all probability some of the flies which he had set free at the head of Manoa Valley "were caught up and carried far into the city of Honolulu, or even away beyond into the sea, miles away from the points of liberation." The writers agree with Severin as to the ability of winds to carry adults considerable distances. The discovery by Mr. H. T. Osborn of an adult upon the summit of Konahuanui (elevation 3,105 feet), the highest peak of the range separating the windward and leeward sides of the island of Oahu, and at a considerable distance above the highest range of host plants, makes it easier for the writers to believe that the few adults which they captured in traps in the scant vegetation on the leeward shore line, and at considerable distances from known sources of infestation, during very windy weather, were specimens caught on the windward side in strong ascending air currents and carried entirely across Oahu. There is no doubt that the adult on Konahuanui observed by Osborn was transported thus from the lower windward levels.

HOST FRUITS.

The writers know of no edible fruit commonly grown in the Hawaiian Islands, except the pineapple, that is not subject to attack by the Mediterranean fruit fly. From a practical trade standpoint the banana should not be considered a host when grown and shipped in accordance with the regulations of the Federal Horticultural Board.

FRUITS ERRONEOUSLY LISTED AS HOSTS.

No infestation has been found in pineapples (*Ananas sativus*), banyan (*Ficus indica*), pride of India or chinaberry (*Melia azedarach*), noni (*Morinda citrifolia*), jujube (*Zizyphus jujuba*), mulberry (*Morus nigra*), tamarind pods (*Tamarindus indica*), wine palm (*Caryota urens*), *Ixora coccinea*, *Canarium commune*, *Sideroxylon sandwichensis*, mammee apple (*Mammea americana*), durion (*Durio zibethinus*), Cape gooseberry or poha (*Physalis peruviana*), ohelo berry (*Vaccinium reticulatum*), kukui nut or candlenut tree (*Aleurites moluccana*), night-blooming cereus (*Cereus triangularis*), and jack fruit (*Artocarpus integrifolia*).

PINEAPPLE.

The pineapple (*Ananas sativus*) is not a host fruit of the Mediterranean fruit fly in Hawaii. Negative data are given here because of the persistent reports that this fruit is subject to fruit-fly attack. Illingsworth reared the pineapple fruit fly (*Dacus xanthodes* Broun) from pineapples in Fiji in 1913. In 1904 Kirk states that he had reared only the Queensland fruit fly (*Dacus tryoni* Frogg.) from pineapples exported from Queensland into New Zealand. In 1908 Kirk again states that *Dacus xanthodes* was commonly found in pineapples and oranges from Fiji and Rarotonga entering New Zealand. Gowdey, in 1913, reports rearing *C. capitata* from pineapples in Uganda, British East Africa. So far as the writers are aware no data have ever been published from careful experiments to determine the true status of the pineapple as a host fruit, and the writers know of no positive evidence that *C. capitata* has ever been reared from this fruit.

It is certain that during a period of over three years not one of seven entomologists in Honolulu has succeeded in rearing adults from this fruit. Fullaway, of the United States Experiment Station, obtained negative results from fruits placed in a large cage. The market and plantation inspectors of the Federal Horticultural Board have brought to the office during the past three years many partially decayed fruits, but no fruit flies were reared from them, although many decay flies were. Although pineapples are grown profitably only under the best horticultural conditions (Pl. III), none of the developing fruits are sufficiently isolated from other varieties of host fruits affected to warrant the belief that adult fruit flies are not present in large enough numbers to infest each fruit were the pineapple susceptible to infestation.

In an attempt to force an infestation within the laboratory, 50 ripe pineapples were placed either singly or by twos in large glass jars containing from 300 to 500 adult flies in a mature egg-laying condition, and allowed to remain with the flies from 2 to 4 days. The pineapples were then removed and placed over sand in covered jars. No flies

were reared from the fruits. The flies readily deposited eggs in apples placed with them both before and after exposure of the pineapples. A record of the time each of the 50 fruits was exposed is as follows:

TABLE VI.—*Nonsusceptibility of pineapples to the attack of the Mediterranean fruit fly.*

Number of fruits exposed.	Dates of exposure to infestation.	Number of fruit flies reared.
	1913.	
2.....	Oct. 14-15.....	None.
1.....	Oct. 17-18.....	
1.....	Oct. 19-22.....	
2.....	Oct. 23-24.....	
6.....	Oct. 27-29.....	
10.....	Oct. 30-Nov. 2.....	
12.....	Nov. 5-7.....	
16.....	Nov. 9-11.....	

During July 18-20, 1913, a very ripe pineapple was hung in a jar containing flies. An examination of the fruit after this two-day exposure revealed 2 punctures in the pulp containing respectively 16 and 11 eggs. One puncture had been made in a slight abrasion; the other in normal tissue between the eyes. Seven other batches of eggs, containing 9, 5, 8, 7, 4, 5, and 4 eggs, respectively, had been deposited on the surface of the fruit, but in the creases between the eyes.

In experimental work the writers have had no difficulty in transferring larvæ from one favored host fruit to another. Experiments in transferring first, second, and third stage larvæ to pineapple invariably resulted in the death of the larva. A total of 925 larvæ were transferred, as follows:

TABLE VII.—*Failure of larvæ of the Mediterranean fruit fly to develop in the pulp of ripe pineapples.*

Date of transfer.	Number larvæ transferred.	Instar when transferred.	Results.
Apr. 22.....	150	Second.....	All died by Apr. 26.
Apr. 23.....	200	do.....	Do.
Apr. 22.....	100	First.....	All died by Apr. 24.
Do.....	25	Second.....	19 dead by Apr. 25; 6 dead by Apr. 26.
Do.....	150	Young third.....	All dead by Apr. 25.
Apr. 23.....	150	do.....	Do.
Apr. 22.....	150	Well grown third.....	Do.

While the experiments above reported indicate that under forced laboratory conditions a few eggs may be deposited within the pulp of very ripe pineapples, the failure of all stages of the larvæ to survive in a medium of fresh ripe pineapple pulp is conclusive evidence that the pineapple should be dropped from lists of host fruits of the Mediterranean fruit fly.

PROVEN HOSTS IN HAWAII.

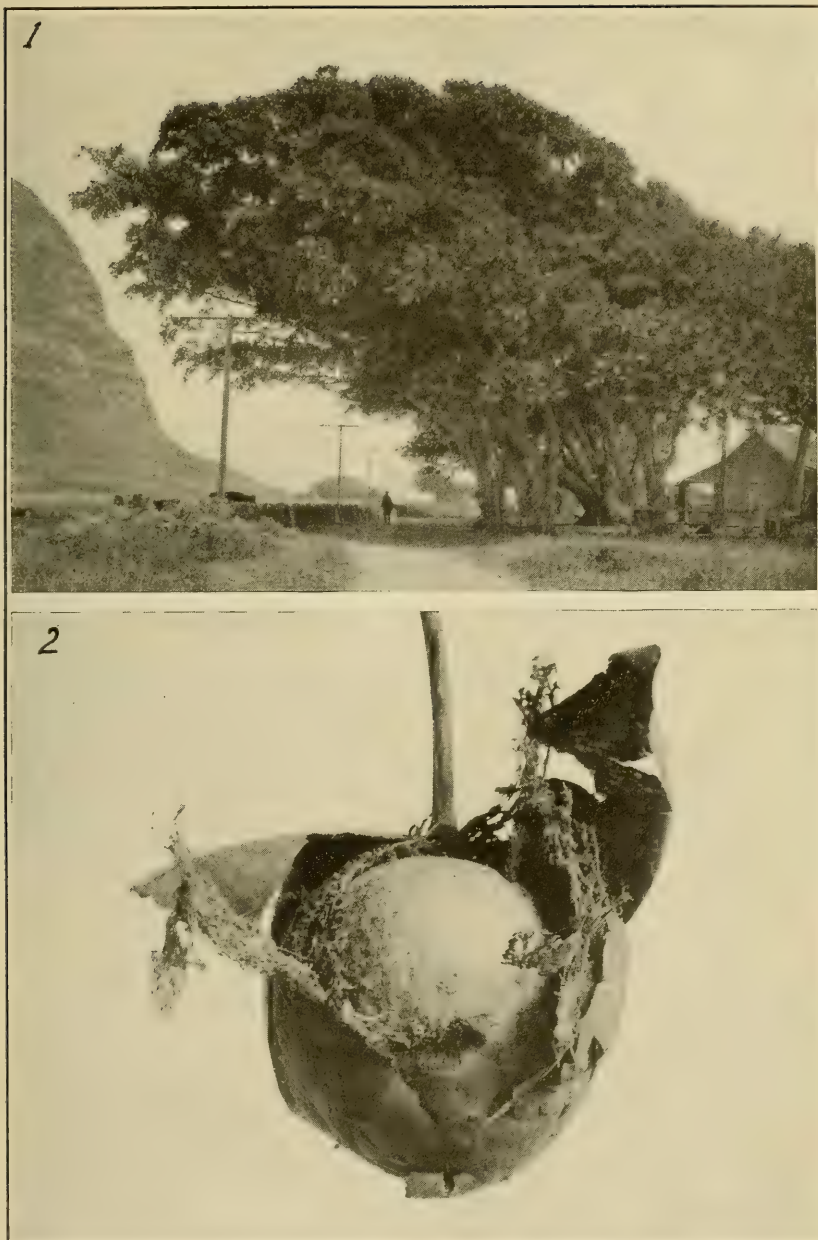
Adults of the Mediterranean fruit fly have been reared from the fruits of the trees, shrubs, and vegetables in the following list. The hosts are arranged alphabetically according to scientific name, and not according to the preferences shown by the fruit fly. The numbers in parentheses refer to the degree of preference for each fruit as a host. Fruits that are heavily or generally infested are marked (1), those that serve occasionally as hosts or of which many escape infestation are marked (2), while those rarely infested are marked (3). The writers appreciate that differences of opinion may arise over any classification of hosts according to degree of infestation, and realize that in colder climates than Hawaii some of the fruits classed as (2) would fall into class 3, or even might not be recorded as hosts at all. The list following represents conditions in littoral Hawaii, particularly about Honolulu:

Hosts of Mediterranean fruit fly in Hawaii.

Scientific name.	Common name.	Scientific name.	Common name.
1. <i>Achras sapota</i> (3).....	Sapodilla.	38. <i>Garcinia mangostana</i> (2)...	Mangosteen.
2. <i>Acordia</i> sp. (3).....	Acordia.	39. <i>Garcinia xanthochymus</i> (2)...	Mangosteen.
3. <i>Anona muricata</i> (2).....	Sour sop.	40. <i>Gossypium</i> spp. (2).....	Cultivated cotton.
4. <i>Arenga saccharifera</i> (3).....	Sugar palm.	41. <i>Jambosa malaccensis</i> (2).....	Mountain apple.
5. <i>Artocarpus incisa</i> (3).....	Breadfruit.	42. <i>Latania loddigesii</i> (3).....	Blue palm.
6. <i>Averrhoa carambola</i> (2).....	Carambola.	43. <i>Lycopersicum esculentum</i> (2).....	Tomato.
7. <i>Calophyllum inophyllum</i> (1).....	Ball kamani.	44. <i>Litchi chinensis</i> (3).....	Lichee nut.
8. <i>Capsicum annuum</i> var. <i>grossum</i> (2).....	Bell pepper.	45. <i>Mangifera indica</i> (1).....	Mango.
9. <i>Carica papaya</i> (2).....	Papaya.	46. <i>Mimulus elengi</i> (1).....	Elongi tree.
10. <i>Carica quercifolia</i> (2).....	Dwarf papaya.	47. <i>Murraya exotica</i> (1).....	Mock orange.
11. <i>Carissa arduina</i> (2).....	Carissa.	48. <i>Musa</i> spp. (3).....	Banana.
12. <i>Casimiroa edulis</i> (1).....	Sapota.	49. <i>Noronhia emarginata</i> (3).....	Noronhia.
13. <i>Cestrum</i> sp. (3).....	Chinese inkberry.	50. <i>Ochrosia elliptica</i> (2).....	Ochrosia.
14. <i>Chrysophyllum cainito</i> (1).....	Star apple.	51. <i>Opuntia vulgaris</i> (2).....	Prickly pear.
15. <i>Chrysophyllum oliviforme</i> (1).....	Damson plum.	52. <i>Passiflora coerulea</i> (3).....	Passion vine.
16. <i>Chrysophyllum polynecium</i> (1).....		53. <i>Persea gratissima</i> (2).....	Avocado.
17. <i>Citrus japonica</i> (1).....	Chinese orange.	54. <i>Phoenix dactylifera</i> (3).....	Date palm.
18. <i>Citrus japonica</i> (1).....	Kumquat.	55. <i>Psidium cattleianum</i> (1).....	Strawberry guava.
19. <i>Citrus nobilis</i> (1).....	Tangerine.	56. <i>Psidium guayava</i> (1).....	Sweet red and white lemon guavas.
20. <i>Citrus nobilis</i> (1).....	Mandarin.	57. <i>Psidium guayava pomiferum</i> (1).....	Common guava.
21. <i>Citrus medica limetta</i> (1).....	Lime.	58. <i>Psidium guayava pyrifera</i> (3).....	Waiwai.
22. <i>Citrus medica limonum</i> (1).....	Lemon.	59. <i>Prunus persica</i> (1).....	Peach.
23. <i>Citrus decumana</i> (1).....	Grapefruit.	60. <i>Prunus persica</i> var. <i>nectarina</i> (1).....	Nectarine.
24. <i>Citrus decumana</i> (1).....	Shaddock.	61. <i>Prunus armeniaca</i> (1).....	Apricot.
25. <i>Citrus aurantium</i> (1).....	Orange.	62. <i>Prunus</i> spp. (1).....	Plum.
26. <i>Citrus aurantium</i> var. <i>amara</i> (1).....	Sour orange.	63. <i>Punica granatum</i> (3).....	Pomegranate.
27. <i>Clausena vampa</i> (3).....	Wampi.	64. <i>Pyrus</i> spp. (1).....	Apple.
28. <i>Coffea arabica</i> (1).....	Coffee.	65. <i>Pyrus</i> spp. (1).....	Pear.
29. <i>Coffea liberica</i> (1).....	Liberian coffee.	66. <i>Santalum freycinetianum</i> (?).....	Sandalwood.
30. <i>Cydonia vulgaris</i> (1).....	Quince.	67. <i>Solanum melongena</i> (3).....	Eggplant.
31. <i>Diospyros discandra</i> (1).....	Persimmon.	68. <i>Spondias dulcis</i> (3).....	W.
32. <i>Eriobotrya japonica</i> (1).....	Loquat.	69. <i>Terminalia chebula</i> (1).....	Natal plum.
33. <i>Eugenia brasiliensis</i> (1).....	Brazilian plum or Spanish cherry.	70. <i>Terminalia catappa</i> (1).....	Tropical almond or winged kamani.
34. <i>Eugenia jambos</i> (1).....	Rose apple.	71. <i>Thevetia nerifolia</i> (1).....	Bestill.
35. <i>Eugenia michelii</i> (1).....	Surinam cherry.	72. <i>Vitis labrusca</i> (3).....	Grape.
36. <i>Eugenia uniflora</i> (1).....	French cherry.		
37. <i>Ficus carica</i> (1).....	Fig.		

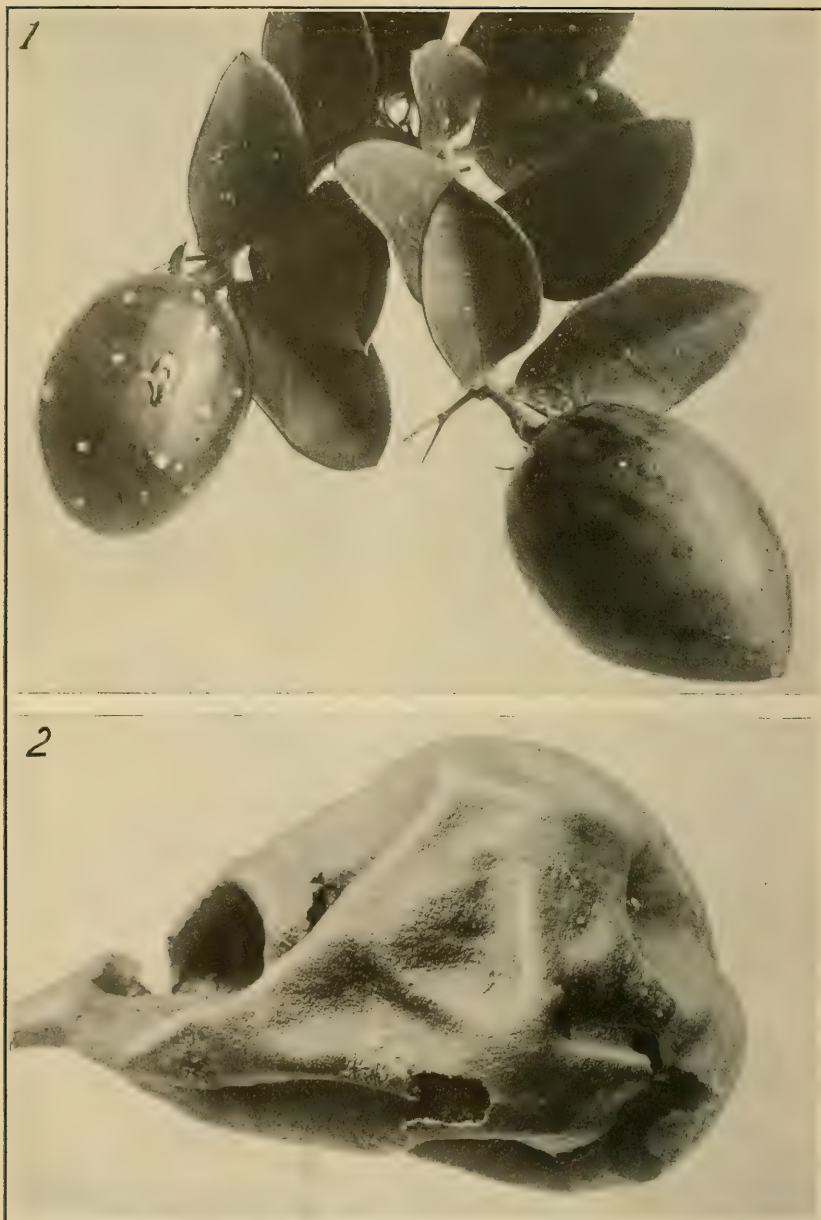
1. SAPODILLA (*Achras sapota*).

The sapodilla or naseberry (*Achras sapota*) is not a preferred host of *C. capitata* in Honolulu. A large percentage of the fruits ripen without becoming infested. Infestations are slight. Only 3 adults were reared from 1 fruit.



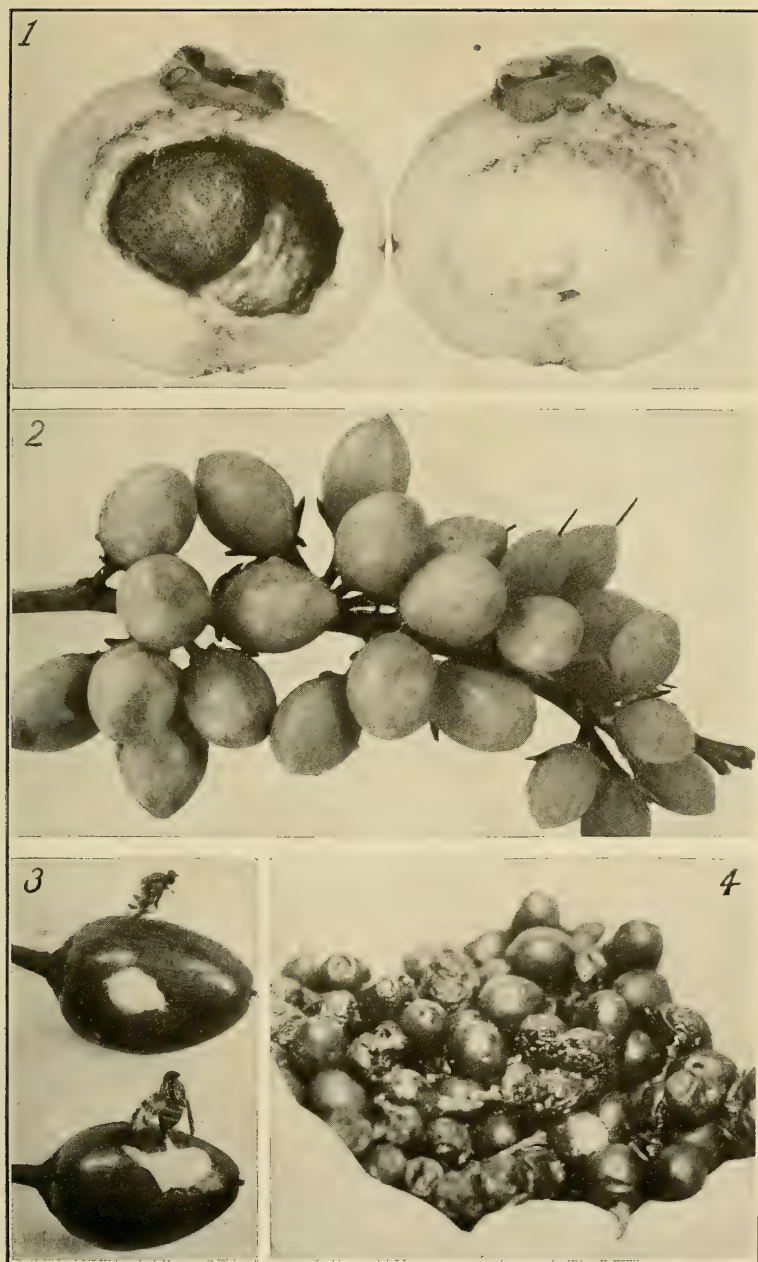
HOST FRUITS OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—A grove of large ball kamani trees (*Calophyllum inophyllum*) producing shade for a country home on windward Oahu. Fruits from these trees are badly infested and are falling throughout the year. FIG. 2.—The inedible fruit consists of a round seed, covered by a thin fibrous pulp in which the larvæ of the fruit fly work. (Original.)



HOST FRUITS OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—*Carissa arduina*. Typical of a class of fruits which are protected from infestation until they are practically ripe by a copious flow of white sticky sap from punctures in the skin made by the adult fly. Note this dried white sap covering punctures on fruits. FIG. 2.—Bartlett pear (*Pyrus* sp.). Fruit-fly larvæ may eat out the entire center of a pear and yet the fruit may remain attached to the tree and shrivel up after the larvæ have fallen to the ground. (Original.)



FOUR FAVORITE HOST FRUITS OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Rose apple (*Eugenia jambos*) sectioned to show the large hollow interior on the surface of which larvae prefer to feed. FIG. 2.—*Mimusops elengi*, fruit of an ornamental tree which sheds its infested fruit throughout a 3 to 4 month period. FIG. 3.—Adult *C. capitata* captured in sticky exudations of solidified sap about punctures in *Chrysophyllum oliviforme*. FIG. 4.—A handful of mock-orange (*Murraya exotica*) berries. The mock orange fruits several times each year and the berries falling become hidden in the grass. (Original.)



2. ACORDIA sp.

The fruit of an *Acordia* with white fleshy pulp was found infested in Bermuda during December, 1913, by the senior writer. The fruit of the *Acordia* in Honolulu, which is a different species and more woody, is not infested.

3. SOUR SOP (*Anona muricata*).

The sour sop (*Anona muricata*) is a fruit which is not ordinarily infested until well grown and is found in the markets in season in perfect condition. Under certain conditions it may become heavily infested. Of 6 overripe fruits, 5 yielded 95, 67, 132, 87, and 2 adults.

4. SUGAR PALM (*Arenga saccharifera*).

A single adult fly was reared from the fruit of the sugar palm (*Arenga saccharifera*) during May, 1912, by the Hawaiian Board of Agriculture and Forestry. From a lot of 14 fruits gathered March 17, 1914, only 3 yielded adults. From these 3 fruits, 1, 4, and 2 flies were reared.

5. BREADFRUIT (*Artocarpus incisa*).

There are no definite records of infestations of the breadfruit (*Artocarpus incisa*). No adults were reared from 100 very much overripe fruits taken from the ground during August, 1914, and placed over sand in jars. Three larvæ were found in one partially decayed fruit, but they were the only ones ever seen by the writers in breadfruit during a three-year period.

6. CARAMBOLA (*Averrhoa carambola*).

The carambola (*Averrhoa carambola*) becomes infested usually only as it ripens, in spite of the fact that it is fragrant and thin skinned. Many fruits escape infestation even in badly infested districts. Of 40 very ripe fruits collected during September, 10 yielded no adults. The other 30 yielded 172 adults, 5 fruits yielding 2, 6, 11, 15, and 20 adults. Only 22 of 62 ripe fruits gathered during August produced adults; from these a total of 289 adults were reared.

7. BALL KAMANI (*Calophyllum inophyllum*).

The ball kamani (*Calophyllum inophyllum*) is badly infested at times (Pl. VI). The adults oviposit very abundantly in the thin, stringy pulp covering the huge seed, as the fruit ripens, but successful larval development often depends largely upon whether the fruit in falling lodges in a place where it remains moist. The fruits on separate trees differ in regard to infestation. On certain trees the pulp may be largely consumed and the larvæ well grown when the fruit falls. Generally speaking, the larvæ in ball kamani are apt to be underfed, their pupæ unusually small, and the adults so depauperized that they may be undeveloped sexually. In a few instances where fruits have fallen in grass on the windward island areas the larvæ have developed to normal size. As many as 120 larvæ have been reared in one fruit. In April, 1913, 7 fruits taken from the ground in Honolulu contained 39, 86, 0, 27, 6, 82, and 115 larvæ. From 104 fruits picked from a tree at Waikiki during April, 1913, 927 larvæ emerged. Of 20 fruits taken from a second tree 11 yielded no adults; the remaining 9 yielded 77 adults, 19 being the largest number from any one fruit. Of 20 fruits of a thick-skinned variety picked from the tree, only 1 yielded adults; a single adult was reared from this fruit. From 1,555 fruits collected during December, 1915, 4,213 larvæ were reared.

8. PEPPERS (*Capsicum annuum* var. *grossum*).

Peppers (*Capsicum annuum* var. *grossum*) grown in market gardens and generally known as "bell" or "green sweet" peppers, and used uncooked in salads, are frequently, although not generally, infested. Five pounds of peppers gathered August 1

at Waikiki, containing very green as well as overripe fruit, yielded no adults when placed over sand in jars. Of 221 ripe peppers gathered at the same place during November, 1915, 213 were not infested; the 8 infested fruits contained from 1 to 5 larvæ each, or a total of 19 larvæ. Thirty-five adults were reared during December, 1913, from 100 ripe peppers, while from 13 peppers collected on March 25, 1913, 14 adults were reared. The fruit fly was first reared from peppers in Honolulu by E. M. Ehrhorn, who reared 6 adults from peppers collected at Kaimuki. While there are reports that all peppers are infested, the writers have never known infestation to exceed 5 per cent of the fruits examined.

Chile peppers (*Capsicum* spp.) have never been found infested by the writers, although many fruits have been under observation.

9, 10. PAPAYA (*Carica papaya* and *C. quercifolia*).

The papaya (*Carica papaya*) is one of the commonest plants about Honolulu and its fruit is the universal breakfast fruit, yet the writers have never seen a fruit sufficiently ripe and fit for eating purposes infested with larvæ. Only fruits too ripe for the table or those having decayed spots are found infested. Sound fruits cut from the tree several days before they soften, a practice which is customary among fruit dealers, are always free from infestation. The milky juice which exudes copiously from cuts in the skin of the fruit contains a digestive principle said to be similar to pepsin. The hands of horticulturists working with the papaya soon become sore if exposed to this juice. It has been shown by Knab and Yothers that the larvæ of the papaya fruit fly (*Toxotrypana curvicauda*) can not live in the pulp of papayas still green, because of this juice. This is true also in the case of *C. capitata* until the fruits are ripe, although several of about 500 eggs introduced artificially into well-grown but still green-colored papayas attached to the tree were able to hatch; the larvæ died. It has been stated in Honolulu that fruits were infested while still green, but the writers have never been able to verify this and all evidence would appear to disprove it.

During January, 1914, an adult female was observed ovipositing in a perfectly sound fruit that was just beginning to turn color. Much juice had exuded around the ovipositor and had formed a gummy semisolid globule. After about 3 minutes the fly withdrew her ovipositor with comparative ease, but the mass of solidified juice remained fast to the tip of the abdomen. The fly freed herself from this mass with considerable difficulty. Seven eggs were found within the puncture, but they failed to develop.

During the winter months very ripe fruits are more heavily infested, as a rule, because of the relative scarcity of other hosts. From 2 fruits picked from the tree on January 18, 1914, 205 and 67 adults, respectively, were reared. Thirty-eight adults were reared from a decayed area in a fruit picked July, 1913. From 6 fruits gathered during May and June, 1913, 27, 13, 49, 2, 30, and 61 adults, respectively, were reared. From one lot of 7 overripe fruits gathered during May only 1 was infested.

The dwarf papaya (*Carica quercifolia*) serves also as a host fruit of *C. capitata*.

11. *Carissa arduina*.

The fruits of *Carissa arduina* are often found generally infested. Even at as late a period in development as that when the fruit has turned deep red, slight abrasions in the thin skin are followed by exudations of white sap which dries about the punctures, as illustrated in Plate VII, figure 1. Every fruit becoming fully ripe on one hedge was found, during February, to be well infested and as many as 30 adults were reared from single fruits.

12. SAPOTA (*Casimiroa edulis*).

The white sapota (*Casimiroa edulis*) is quite generally infested about the time it ripens. Practically every ripe fruit falling to the ground is variously infested. As many as 40 adults have been reared from a fruit 2 inches in diameter. While green the fruits are protected by white sap which exudes copiously from skin abrasions.

13. CHINESE INKBERRY (*Cestrum* sp.).

The Chinese inkberry (*Cestrum* sp.) is seldom infested, although the trees produce an abundance of fruit. Samples of several hundred fruits, each taken from the ground among badly infested coffee trees, have yielded no adults. In one instance 3 adults were reared from fruits collected by the Hawaiian Board of Agriculture in Manoa Valley in November, 1911.

14. STAR APPLE (*Chrysophyllum cainito*).

The star apple (*Chrysophyllum cainito*) is a preferred host and is always grossly infested. The writers have not observed a single mature fruit during the past three years that was uninfested. The milky, sticky juice exudes from abrasions in the skin until the fruit is overripe. Often, as is the case with other species of *Chrysophyllum*, this juice solidifies so rapidly that the female fruit fly is caught by the ovipositor and held captive until death. From four very ripe fruits collected at Haleiwa, May 30, 1913, 188, 110, 105, and 5 adults, respectively, were reared. Five fruits from the same tree, picked May 27, 1914, yielded 18, 96, 54, 105, and 44 adults, respectively.

15. DAMSON PLUM (*Chrysophyllum oliviforme*).

The small plum *Chrysophyllum oliviforme* is one of the preferred hosts of *C. capitata*. Like its relative, the star apple (*Chrysophyllum cainito*), it is well protected by the white sticky juice which exudes rapidly from breaks made in its skin until quite well grown. (Pl. VIII, fig. 3.) Although larvæ develop to a very large size in this fruit and scarcely a fruit ripens uninfested, the average number of larvæ per fruit is small. Of a sample of 48 fruits collected during February, 18 produced no adult flies. From the remaining 30 fruits an average of 2.4 adults resulted, 14 being the largest number of adults reared from a single fruit.

16. *Chrysophyllum polynecium*.

This fruit, which is round and about half an inch in diameter, is congeneric with the star apple (*Chrysophyllum cainito*) and the Damson plum (*Chrysophyllum oliviforme*). Like them it is a preferred host and always grossly infested. From two lots of 500 fruits each gathered from the ground during May, 1914, 1,584 and 1,140 adult flies were reared.

17-26. CITRUS FRUITS.

In a previously published paper¹ on the susceptibility of citrus fruits, the writers present data secured under Hawaiian conditions which show why such thin-skinned fruits as the tangerine, mandarin, Chinese orange, and kumquats are readily infested, and why oranges, lemons, and grapefruit resist infestation of the pulp with such remarkable success. All varieties of citrus have been found in Hawaii containing well-grown larvæ of *C. capitata* in their pulp and first-instar larvæ transferred to the sourest, and even half-grown lemons have been reared to the adult stage, so there is no question as to the correctness of classifying all citrus fruits among the hosts of *C. capitata*. While it seems evident that the acidity of partially ripe lemons has a detrimental effect upon larval growth, it has been proved experimentally and by field observation, both by Quayle and the writers, that no fruit is too acid for larval development. Savastano, in 1914, giving the results of experimental work carried on in Italy, exaggerates the part played by the acidity of citrus fruits in protecting them from *C. capitata* attack. In Hawaii his conclusions have not been borne out by the results of investigations by the writers. The data in Table VIII are presented in detail because of the difference of opinion existing between investigators as to the cause of egg and larval mortality in the citrus groups. The conclusions of the writers, based upon extensive examinations,

¹ Back, E. A., and Pemberton, C. E., Susceptibility of citrus fruits to the attack of the Mediterranean fruit fly. Jour. Agr. Research, v. 3, no. 4, Jan. 15, 1915.

are that, in Hawaii at least, citrus fruits resist fruit-fly infestation of their pulp in proportion to the thickness and texture of the rag underlying the rind, the quantity of oil liberated from the oil cells during the process of oviposition, and their ability to develop quickly about the egg cavity the gall-like tissues which so often make of the cavity a prison for the larvæ that hatch. The data in Table VIII emphasize the large numbers of eggs deposited in the skin of *Citrus* spp., and the relatively small number of these that produce larvæ able to reach and enter the pulp except in the Chinese oranges, limes, and tangerines. Larvæ that succeed in entering the rag from the egg cavity in the rind are unable to reach the pulp except in astonishingly small numbers because of the imperviousness of the rag. It is the persistent attack of successive lots of larvæ hatching from different batches of eggs, laid very often in the same puncture, that finally breaks down the barrier between the young larvæ and the pulp. If the types of mortality among eggs and larvæ in the rind of oranges, grapefruit, and lemons protect those fruits so well under Hawaiian conditions, where the weather is so warm that the adult flies can deposit their eggs every day in the year, they should constitute a valuable factor in control when supplemented by climatic cultural conditions more adverse to the development of *C. capitata* in other countries.

TABLE VIII.—*Infestation of citrus by the Mediterranean fruit fly.*

Fruit.	Punctures.		Eggs, appearance.		Larvæ.					
					Alive.			Dead.		
	Empty.	Not empty.	Normal.	Abnormal.	In puncture.	In rag.	In pulp.	In puncture.	In rag.	In pulp.
Chinese orange:										
1.	0	2	15				6			
2.	0	1					4			
3.	0	1					8			
4.	0	2	9				5	4		4
5.	0	1					9			
6.	0	1		26						
7.	0	1					7			
8.	1	1					19			
9.	0	1					3			
10.	0	1						1		6
11.	0	1							6	
12.	0	4	15				12			
13.	0	3		12			7			
14.	0	1					11			
15.	0	1					5			
Lime:										
1.	10	0							13	
2.	6	5	15							
3.	7	4	34					4	4	
4.	4	6						10	30	
5.	1	5	53	1			1	21	1	
6.	6	9		1				20	15	
7.	0	7	33				9	33		
8.	3	5	80	2				9	11	
9.	3	0								
10.	8	9		15				56	4	
11.	0	9							49	
12.	6	5	61	27				6	3	
13.	4	2						7		
14.	9	2	15					2		
15.	7	7	44					9	17	
16.	5	0								
17.	11	0								
18.	5	13		14				14	37	
19.	7	9						30	12	
20.	5	0								
Grapefruit:										
1.	7	25	83	514				19	28	
2.	1	12	369	111		1		26	4	
3.	0	3	17	16	1			10		
4.	2	3	4						5	
5.	5	6	42	9				4		
6.	7	14	43	203				13	45	

TABLE VIII.—*Infestation of citrus by the Mediterranean fruit fly*—Continued.

Fruit.	Punctures.		Eggs, appearance.		Larvæ.					
					Alive.			Dead.		
	Empty.	Not empty.	Normal.	Abnormal.	In puncture.	In rag.	In pulp.	In puncture.	In rag.	In pulp.
Grapefruit—Contd.										
7	8	14		484				17	7	
8	4	19	9	666				10	7	
9	2	4		69				59	61	
10	5	24		404					89	
11	1	11		232				5		
12	14	8	32	75	8			25		
13	0	27	5	385				3		
14	0	18	88	208				4	9	
15	0	5		86	3					
16	0	11	8	195				19	15	
17	0	6		42	8			6		
18	0	4		74						
19	0	10		307						
20	0	13		329				29		
Lemon:										
1	3	4	23		1 20			4		
2	0	2	30					13		
3	5	0								
4	4	1		7						
5	14	4	15					18		
6	2	2	3					9		
7	3	2	5					4		
8	4	0								
9	28	12	47	60				14		
10	8	3	15	12						
11	6	10	129	32				2		
12	11	5	39	15				1		
13	9	5	38	2						
14	15	1	10					1		
15	4	0								
16	16		64						5	
17	8	2	10							
18	1	0								
19	7	0								
20	12	15	19	53				82		
21	30	3	11							
22	53	10	23	21				9		
23	12	3		18				20		
24	11	5		45				12		
25	5	2		3				3		
26	5	0								
27	2	4	14	1				4	10	
28	6	22	0	71				32		
29	2	1	44							
30	4	8	62	20				12		
31	4	1	0	7						
32	11									
33	6	12	67	122				16		
34	4	2						7		
35	4	2	16					5		
Sweet orange: ²										
1	2	7						41	10	
2	13	11						42	29	
3	0	2							25	
4	2	5						15	5	
5	2	3						14	3	
6	0	1							6	
7	0	12						17	45	
8	5	16						83	6	
9	1	1		4						
10	2	8						37	27	
11	0	2						11		
12	2	5						19	26	
13	1	4						36	12	
14	1	5						13	19	
15	1	9					3 5	6	94	
16	7	17	21					75	58	

¹ These 29 newly hatched larvæ were feeble and appeared to be about ready to die.² Fruits of sweet oranges 1 to 13 picked Mar. 7, examined Mar. 10, 1914; 14 to 20 picked Feb. 24, examined Mar. 6 and 7, 1914; 21 to 23 picked Sept. 10, examined Sept. 16, 1913; 27 to 29 picked Sept. 10, examined Sept. 18, 1913; 30 picked Sept. 4, examined Sept. 15, 1913.³ Third-instar larvæ in pulp; orange not decayed.

TABLE VIII.—*Infestation of citrus by the Mediterranean fruit fly*—Continued.

Fruit.	Punctures.		Eggs, appearance.		Larvæ.					
					Alive.			Dead.		
	Empty.	Not empty.	Normal.	Abnormal.	In puncture.	In rag.	In pulp.	In puncture.	In rag.	In pulp.
Sweet orange—Con.										
17.....	0	8	.....	.....	.....	.....	.....	0	45	.....
18.....	2	11	.....	.....	.....	.....	.....	.....	79	.....
19.....	6	4	.....	.....	.....	.....	.....	3	25	.....
20.....	5	5	.....	9	.....	.....	12	19	10	.....
21.....	7	20	3	25	.....	.....	.....	107	63	.....
22.....	15	18	7	24	.....	.....	.....	66	51	.....
23.....	8	9	.....	33	.....	.....	.....	7	29	.....
24.....	29	16	12	68	.....	.....	.....	18	37	.....
25.....	4	13	14	21	.....	.....	.....	48	65	.....
26.....	3	10	.....	21	.....	.....	.....	35	13	.....
27.....	4	9	40	30	.....	.....	.....	27	6	.....
28.....	10	12	25	52	.....	.....	.....	.....	37	.....
29.....	.....	.....	13	17	.....	.....	.....	52	40	.....
30.....	12	11	150	36	.....	.....	.....	.....	.....	.....
Sour orange: ²										
1.....	5	5	11	15	.....	9	.....	.....	1	.....
2.....	2	6	0	94	.....	.....	.....	31	.....	.....
3.....	3	8	19	15	.....	.....	.....	6	.....	.....
4.....	2	8	30	32	.....	.....	11	.....	.....	.....
5.....	0	8	12	10	.....	.....	.....	37	.....	.....
6.....	3	10	75	250	.....	.....	.....	32	14	.....
7.....	2	8	4	45	.....	.....	.....	24	7	.....
8.....	1	7	7	57	.....	.....	59	16	.....	.....
9.....	1	7	0	4	18	.....	7	23	10	.....
10.....	4	9	10	48	.....	.....	.....	43	.....	.....
11.....	1	27	12	48	.....	.....	28	51	.....	.....
12.....	1	12	36	116	.....	.....	.....	36	.....	.....
13.....	1	5	0	25	.....	.....	.....	16	7	.....
14.....	2	2	10	14	.....	.....	25	.....	.....	.....
15.....	0	2	0	9	.....	.....	36	.....	.....	1
16 ³.....	.....	.....	.....	.....	.....	.....	49	.....	.....	.....
17.....	7	0	.....	.....	.....	.....	.....	.....	.....	.....
18.....	2	1	5	.....	.....	.....	.....	.....	.....	.....
19.....	4	4	57	12	.....	.....	.....	.....	.....	.....
20.....	1	2	0	44	2	.....	.....	.....	.....	.....

¹ Third-instar larvæ in pulp beneath soft but undecayed spot in rind.² Fruit of sour oranges, 1 to 16 picked Mar. 3, examined Mar. 10 and 11, 1914; 17 to 20 picked Sept. 4, examined Sept. 5, 1913.³ Very badly decayed.

17-21. CITRUS FRUITS EASILY INFESTED IN HAWAII.

The varieties of *Citrus japonica* in Hawaii known as the Chinese orange and the kumquats ("testa di turco" of the Italians), of *Citrus nobilis*, known as the mandarin and tangerine, and of *Citrus medica limetta*, or lime, are easily infested by *C. capitata*. The data of Table VIII on the infestation of Chinese oranges and Hawaiian limes are introduced as examples of infestation for the varieties of *C. japonica* and *C. nobilis*. The rind of the Chinese orange and of many limes, mandarins and tangerines is so thin that the adult fly is able to deposit eggs either directly within the pulp or between the rind and the skin covering the pulp, but parallel with the rind and at a slight distance away from the ruptured oil cells where they more often escape the fatal action of the oil or hindrances in the form of a dense rag. Of 609 eggs deposited between the rind and the pulp in Chinese oranges, 98.5 per cent hatched and the larvæ, unhindered by the presence of an impervious rag, entered the pulp. The infestation of the pulp of limes, tangerines and mandarins is in inverse proportion to the thickness of the rind. It is interesting to note that eggs in the Kusaie limes, the rind of which is sufficiently thick so that the eggs are usually deposited directly beneath the puncture, die with great regularity, while the eggs in Hawaiian limes, the rind of which may be sufficiently thin to permit the eggs being deposited as in Chinese oranges, or so thick (according to

the individual tree) that the eggs are laid either in the cavity in the rind, or between the rind and pulp but directly beneath the puncture, suffer a degree of mortality between that of eggs deposited in Chinese oranges and Kusaie limes. Mandarins and tangerines in Hawaii usually are infested if allowed to ripen thoroughly upon the tree. The Satsuma orange is a fruit that easily becomes infested because of the looseness of the rind and lack of well-developed rag.

22. LEMON.

Because of the danger of introducing the Mediterranean fruit fly from the Mediterranean regions in lemons, the importance of this fruit as a host has been thoroughly investigated at the request of Mr. C. L. Marlatt, chairman of the Federal Horticultural Board. The observations of Martelli and Savastano in Italy have led them to definite statements as to the immunity of commercial lemons to *C. capitata* in Italy. H. J. Quayle, who conducted an investigation during 1913 in the Mediterranean citrus regions under the direction of the Federal Horticultural Board, found less than 15 lemons with infested pulp during a search of eight weeks throughout commercial lemon orchards in Italy and Sicily. It is interesting to record that of the 15 fruits containing larvæ within the pulp, all had the appearance of having been injured, either mechanically or by fungi, and in all but two instances they were found in an overripe and overdeveloped condition on the ground beneath the trees. The two fruits found infested while still attached to the tree were partly decayed on one side. These instances of infestation recorded by Quayle, who is thoroughly competent to judge from long experience with citrus in California, refute the argument that lemons are too acid to support *C. capitata* larvæ, although the small number of lemons found infested, of the thousands examined during the eight-week period, strengthens the argument set forth by the Italian entomologists, as well as by the writers, that lemons, commercially grown and cured, will not support the fruit fly if they are not first subjected to some mechanical or other injury while still attached to the tree.

In Hawaii, where climatic and host conditions are so favorable to *C. capitata* activity and where every host is subjected to the severest tests, the writers have never found a lemon of either the commercial or the rough-skinned type showing infestation of the pulp unless it had first received mechanical injuries. Although there are comparatively few lemon trees in Hawaii, those known to the writers have seldom been found infested. By "infested" is meant, in this instance, an infestation by *C. capitata* larvæ in the pulp. Out of 235 well-grown and for the most part ripe lemons of the commercial type, picked from the tree, only one eventually developed adults, three in number, and this fruit when picked was partially decayed as the result of a thorn prick. Out of 161 lemons of the same variety taken from the ground in a very much overripe condition, only two developed larvæ, 1 and 5, respectively. No larvæ developed in 434 ripe, rough-skinned, but badly punctured lemons picked from the tree. One partially decayed rough-skinned lemon picked from the ground produced 12 larvæ. These instances of infestation of the pulp, taking place in the field, are the only ones which have come to the attention of the writers during the past four years in Hawaii.

The recording of so small a number of lemons with larvæ developing in their pulp should not be interpreted as meaning that lemons are particularly free from attack in Hawaii. The data of Table VIII prove that, in reality, lemons of the commercial type grown in Hawaii are very attractive to adult *C. capitata* as host fruit. The many fruits listed above from Hawaii from which no adults were reared were as heavily infested in the peel as those recorded in Table VIII. Particular attention is drawn to this point since it is the contention of the writers that the immunity of lemons, otherwise uninjured, is due not so much to the acidity of the pulp as it is to the imperviousness of the rag. It seems incredible that lemons heavily oviposited in should be able to resist successfully infestation of their pulp, yet this is true. Examination of 5 lemons showed that 73 of 79 egg cavities or punctures had been made between the

oil-cells, hence the immunity of lemons is due chiefly to the imperviousness of the rag and the gall-like developments about the egg cavity which make it difficult for the hatching larvæ to leave the cavity.

In the laboratory a comparison was made between the infestation of the rind of cured California lemons and well-grown fruits picked fresh, both green and yellow in color, from the trees. About the egg cavities in freshly picked fruits infested by adults in the laboratory, a hard, more or less gall-like condition of the walls and adjoining tissues develops rapidly. In the well-cured fruits no such gall-like hardenings were detected following infestation, and after hatching the larvæ had little difficulty in working their way out of the puncture into the rag. Thus six California-grown lemons such as are found on the markets were exposed between April 3 and 5, 1915, in large glass jars containing each about 200 flies. After removal they were held until April 12, when an examination showed them to have been oviposited in 16, 26, 31, 29, 39, and 20 places, respectively. Of the 161 punctures, only 8 had been made in, or through, an oil-cell and in these the *C. capitata* (numbering, respectively, 2, 1, 1, 3, 0, 2, 5, and 8) were dead. From the remaining 153 punctures, made between the oil-cells, 441 larvæ had escaped into the rag beneath, where, without exception, they were found dead. Other well-grown but greenish colored lemons were gathered from the trees and immediately exposed to adults within similar glass jars between April 14 and 16, 1915. These fruits were examined April 19-20. Before being exposed in the jars all punctures in the rind, made previously in the field, were covered with gummed paper. The results of the examination of two of these fruits are given here as typical:

Fruit No. 1.

- Puncture 1. One dead larva in puncture located between oil-cells.
 2. One unhatched egg in puncture in oil-cell.
 33. Three unhatched eggs in puncture between oil-cells.
 4. Six unhatched eggs in puncture between oil-cells.
 5. Two larvæ barely alive in rag beneath puncture made between oil-cells.
 6. Five unhatched eggs in puncture between oil-cells.
 7. Seven unhatched eggs in puncture between oil-cells.
 8. Four unhatched eggs in puncture between oil-cells.
 9. Six dead larvæ in puncture between two oil-cells.
 10. One dead larva in puncture between two oil-cells and one dead in rag close by.
 11-19. These nine punctures were shallow and contained nothing.

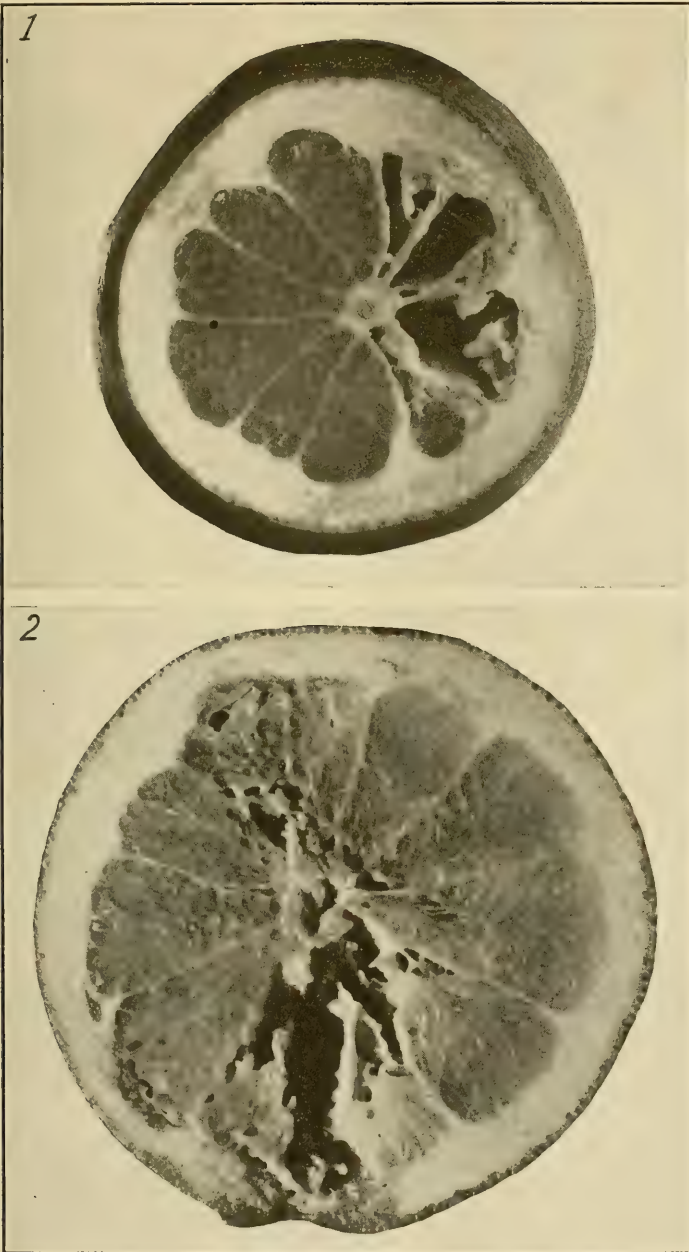
Fruit No. 2.

- Puncture 1. Nine dead larvæ in rag beneath puncture between oil-cells.
 2. One dead larva in puncture made between oil-cells.
 3. Four dead larvæ in puncture made between oil-cells.
 4. Three unhatched eggs in puncture made between oil-cells.
 5. One dead first-instar larva in rag beneath puncture made between oil-cells.

These data indicate the way citrus fruits are protected from infestation of the pulp, and they supplement previously published data on the development of larvæ within lemons.

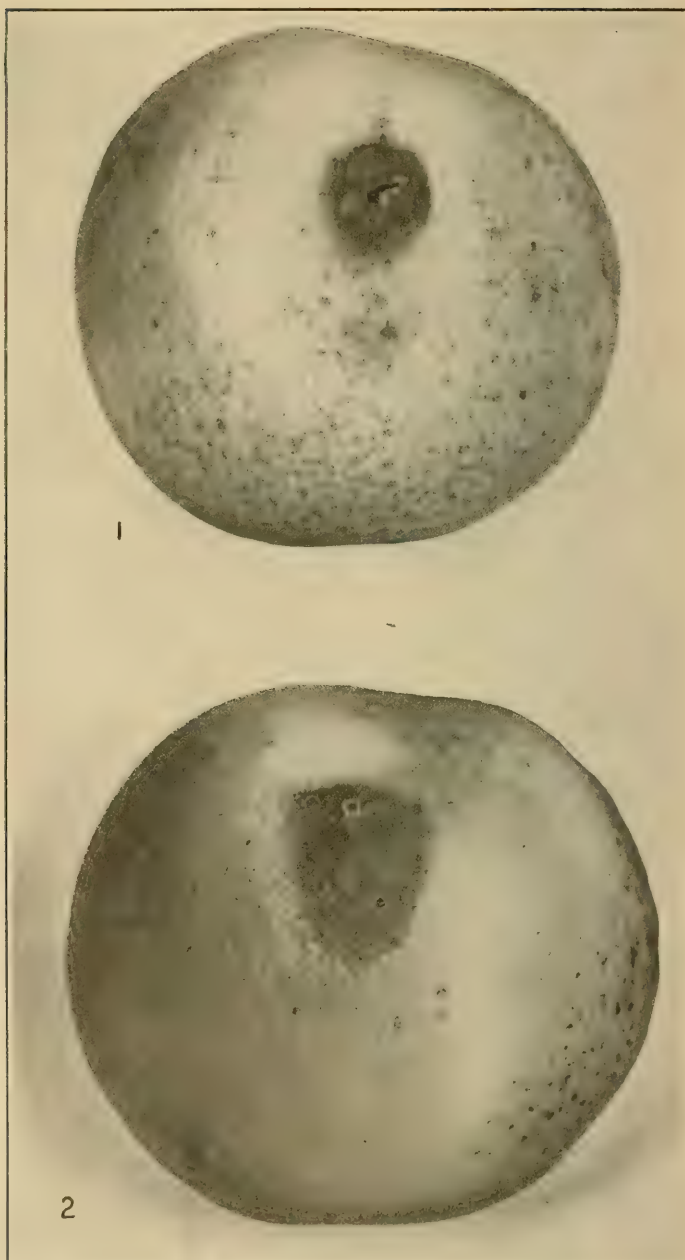
23. GRAPEFRUIT.

The ordinary types of grapefruit which have come under the observation of the writers have been particularly resistant to attack up to the time when they are fit for table use as indicated by the data of Table VIII. These data were secured during September. Many fruits from these trees in Manoa Valley, Honolulu, which were sufficiently ripe to fall to the ground, have been held over and in the laboratory but yielded no adult flies. The writers have found other trees bearing fruits with rinds of a looser texture from which they have reared adults, and in certain instances have found fruits still attached to the trees, which, though much overripe, were badly infested. It seems very probable, therefore, that should the fly reach the citrus regions of the mainland, certain thin-skinned varieties of grapefruit might



GRAPEFRUIT AS A HOST OF THE MEDITERRANEAN FRUIT FLY.

Two types of infestation. FIG. 1.—Larvæ have eaten out a portion of the fruit while the rest remains unaffected. FIG. 2.—Infestation extending throughout the pulp. Note that the rind shows evidence of infestation of the pulp only at the decayed spot on the lower side. (Original.)



THE ORANGE AS A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Orange infested with larvæ of the Mediterranean fruit fly. Note that the fruit looks sound, except about the irregular hole, through which a few well-grown larvæ have already left the fruit. FIG. 2.—Orange infested with larvæ of the Mediterranean fruit fly showing two breathing holes of the larvæ in the decayed area. (Author's illustration.)

become seriously infested unless gathered and sold early. Three grapefruit out of five dropping from the tree in an overripe condition, two months after they had been marked as sufficiently ripe for eating, produced four, two, and four adults. It is interesting to record that when these five fruits were marked they already had been oviposited in. E. M. Ehrhorn reared 16 adults from an overripe grapefruit grown in the Punahou district of Honolulu during November, 1911. The grapefruit grown at ex-Gov. Frear's city and mountain residences have been found infested when much overripe. The fruits used as illustrations (Plate IX) were taken from Tantalus during a particularly wet season when it appeared to the writers that the action of numerous showers had aided the larvæ in breaking down the protective rag of the rind.

The exudation of gum from punctures does not always occur, although at times it may be very excessive in Hawaii.

24. SHADDOCK.

The large, very thick-rinded shaddocks are not infested successfully until they are very much overripe. During March, 1914, fruits were gathered from a tree in Hilo, Hawaii, from which fruits had been taken for the table during the months of January and February. During those months no infestation of the pulp had been noted by the owner. Examinations made of the bag end of the crop showed that larvæ had successfully penetrated the pulp and had been able to burrow about through the loose-textured rag. Instances were found in which the larvæ had completed their entire development within the rag. As many as 22, 17, 9, 17, 16, 25, 19, 8, 1, and 18 living larvæ were found in the rag of 10 fruits. Of these 10 fruits only four possessed 27, 13, 3, and 12 living larvæ in the pulp. On examination, made at the same time, of equally ripe fruits of another shaddock tree that possessed a firmer rag, there were found 6 normal and 39 abnormal appearing eggs; 5, 2, and 3 living larvæ in the punctures, rag, and pulp, respectively; and 405, 696, and 1 dead larvæ in the punctures, rag, and pulp, respectively.

25. SWEET ORANGES.

Oranges are subject to severe attack from the time they are nearly grown until they fall to the ground or are picked. (See Pl. X.) Ten oranges just beginning to turn color, collected in Honolulu in November, 1915, had 14, 33, 74, 4, 22, 13, 99, 11, 20, and 14 punctures, respectively, in their rind; 10 others of another crop gathered during June, 1913, had 29, 17, 34, 14, 11, 17, 33, 17, 18, and 17 punctures, respectively. Ten ripe fruits picked in the same general locality as these 20 fruits during October, 1915, had 21, 2, 17, 10, 10, 3, 2, 46, 9, and 3 punctures, respectively. In spite of the fact that 39 oranges picked in September when they were just becoming well yellowed had an average of 32 punctures per fruit, none of them developed larvæ within the pulp. But of 784 oranges gathered during March, 1914, when very much overripe, 254 produced 2,272 larvæ, or an average of 9 larvæ to the fruit. Such data as these, coupled with the more detailed data of Table VIII, throw much light on the wonderfully resistant power of oranges to fruit-fly attack. Were oranges not so well equipped by nature to withstand attack they would be ruined long before any of them could ripen. Considering the number of eggs deposited, very few adults emerge even from fruits that become infested in the pulp. Thus, only 5, 13, 4, 1, 6, 12, 6, 30, 8, 4, 1, 1, 14, 26, 1, 12, 31, and 2 adults were reared from 18 fruits picked because they appeared to be badly infested.

26. SOUR ORANGES.

The ordinary sour orange commonly found in Florida groves is as severely attacked as is the sweet orange, but on account of the looseness of the rind and rag it becomes infested in the pulp more easily. A larger percentage of fruits become infested in the pulp when well ripened than of sweet oranges. (See Table VIII for data on infestation.)

27. WAMPI (*Clausena wampi*).

The wampi (*Clausena wampi*) is a native of China. While a large percentage of the fruit produced by a tree growing at Beretania and Punahou Streets, Honolulu, was found free from attack during June, 1914, certain overripe fruits contained larvæ of *C. capitata*. From 200 fruits gathered during July, 1913, only four adults were reared.

28, 29. COFFEE.

Coffee cherries (*Coffea arabica* and *C. liberica*) are favorite hosts of the Mediterranean fruit fly. *Coffea arabica* is grown in various portions of the Hawaiian Islands, but commercially, at the present time, only on the island of Hawaii. (Pl. V.) During the fiscal year ended June 30, 1915, there were exported from the islands 4,363,606 pounds of raw coffee beans valued at \$651,907, besides the coffee locally consumed. Fortunately for the coffee growers in Brazil and Africa, as well as in Hawaii, the larvæ of the fruit fly attack only the pulp of the cherry surrounding the beans or seeds and in no way affect the value of the latter. The chemical analyses of Miss A. R. Thompson, formerly of the United States experiment station at Honolulu, have proved that beans from infested cherries do not differ chemically from those from uninfested cherries, and tasting tests of coffee made from roasted beans by Messrs. L. Macfarlane and Robert Wallace, coffee growers of Hawaii, Mr. H. L. Lang, of the office of Home Economics of the United States Department of Agriculture, Dr. E. V. Wilcox, formerly director of the Hawaii Federal Experiment Station, and the writers have failed to discover differences in either the flavor or the aroma.

The unrestricted development of larvæ within coffee cherries does, however, bring about certain losses to the growers and mill owners that are apt to be overlooked except by those best informed. Before the introduction of parasites into the coffee districts cherries were infested, often as soon as they began to turn white from green, in the final ripening process. The larvæ, numbering from 2 to 8, were able to become nearly full grown by the time the cherries had turned red. An examination of the coffee cherries as illustrated (Pl. V, fig. 4) shows that the beans occupy the larger portion of the fruit. The pulp itself, with its thin, easily punctured epidermis, varies in thickness from 0.04 to 0.14 inch, or is scarcely thicker than a well-grown larva of the fruit fly. Therefore, by the time the cherry would ordinarily be ready for harvesting the larvæ have devoured practically all the pulp, leaving the seeds hanging more or less loosely within a sack composed of the thin epidermis. If the weather happens to be dry, the epidermis shrivels and hardens about the beans and the cherry remains on the branch indefinitely, resembling closely those killed by disease. However, should the harvesting season be rainy, the epidermis decays rapidly and under the weight of the beans the cherry falls to the ground. The writers have been in certain coffee fields where a slight jar to the tree would cause many cherries to fall to the ground, where they are lost. This type of loss necessitates extra pickings and greater cost of labor. Since the successful introduction of parasites the fruit fly has been so reduced, as discussed on page 99, that while cherries are infested in about the same proportion as formerly, the infestation occurs so late in the ripening process that extra pickings now are not necessary and the cherries on reaching the mills during the height of the harvesting season contain chiefly eggs or young larvæ which have not had an opportunity to reduce the pulp. Whether these improved conditions of 1914 and 1915 will continue remains to be seen.

For some time after the advent of the fruit fly into the coffee districts, prices for coffee in the cherry delivered at the pulping mills remained the same per pound. During 1912 and 1913 when the fly attack was severe it was difficult to find at the mills cherries which were normally bright red and sound. Practically every cherry that was red was badly infested and its pulp had been consumed, and the floors about the delivery platforms were well strewn with emerging larvæ. As the pulp only had been destroyed, a pound of coffee cherries badly infested contained in reality many

more coffee beans, or of that portion of the cherry that had any commercial value. Counts made of samples of badly infested cherries, and of those in which the infestation had not progressed sufficiently far to affect the weight, were made and the loss both in numbers and percentage of cherries is given in Table IX.

TABLE IX.—*Loss of weight and pulping quality of coffee cherries due to infestation by Mediterranean fruit fly.*¹

Weight of sample.	Number of cherries.		Loss due to infestation.		Cherries failing to pulp.		Cherries partly pulped.	
	Badly infested.	Firm bright red.	In number of cherries.	In percentage.	Badly infested.	Firm bright red.	Badly infested.	Firm bright red.
6 pounds.....	3,060	1,980	1,080	54.5	692	0	334	25
10 pounds.....	3,675	2,892	783	27.1	833	11	699	227
4 pounds.....	1,828	1,277	551	43.1	274	3	357	274
3 pounds.....	1,171	736	435	59.1				
10 pounds.....	3,562	2,561	1,001	39.8				

¹ Attention is called to the fact that differences in the size and succulency of coffee cherries is responsible for the differences in the number of cherries per pound in the different samples. While several ordinary weighing machines were used in securing data in Tables IX and X, the uninfested and infested cherries or beans of the same sample were weighed on the same machine.

It will be noted that loss in the number of coffee cherries due to heavy infestation, when the cherry is sold by the pound at prices paid before the advent of the fly, ranged in the particular examples taken from 27.1 to 59.1 per cent. In practice, however, this loss is considerably reduced by the addition of half-ripe fruits in the fields. This loss has been appreciated by the small Japanese coffee growers and has been responsible, in the opinion of the writers, for the erection of many small pulping mills throughout the Kona coffee district. It has also encouraged coffee renters who deliver their crop at the large mills to put in their sacks a high percentage of "too-green" cherries which will not pulp and are therefore lost.

Badly infested cherries do not pulp as easily as do sound fruits, as shown in the data of Table IX. Thus in 6, 10, and 4 pounds of badly infested cherries, run through a gasoline pulping mill, 692, 833, and 274 failed to pulp, whereas in three samples of the same weight of unaffected cherries, 0, 11, and 3 cherries failed to pulp. The number of badly infested cherries that only partly pulped is also much larger than that of unaffected cherries.

To determine whether the beans from infested and noninfested cherries differed in weight after they had been dried and sacked for several months the beans of 1,000 cherries were weighed separately with the results given in Table X.

TABLE X.—*Relative weights of thoroughly dried beans from badly infested and uninfested coffee cherries.*

Weight of sample of dried beans from 1,000 cherries.					
Lot.	Infested.	Not infested.	Lot.	Infested.	Not infested.
	Ounces.	Ounces.		Ounces.	Ounces.
1.....	11	11	3.....	10	10
	11	11.5		10.5	10.5
	10.5	11		12	12
	9.5	10		11.5	11
	10	10	4.....	11	11.5
2.....	9.5	10		12	12
	9.5	9.5		12	12
	9.5	9.5			

The data indicate that the weight of the bean is not affected by infestation.

In experimental work coffee cherries should be avoided, if possible, as a source of fruit-fly larvæ unless one is working close to coffee fields. While from 2 to 8 larvæ may mature in each fruit if the fruit remains attached to the tree, the fruit heats and decays so rapidly after being picked and placed in containers that only a relatively small number of adults can be reared. Only 427 adults were reared from 1,500 ripe infested cherries placed over sand in lots of 25. If these cherries had been allowed to remain on the tree they would have produced at least 6,000 adults.

30. QUINCE (*Cydonia vulgaris*).

The quince (*Cydonia vulgaris*) is not grown in Hawaii, but fruits obtained from the mainland were readily infested. The quince is frequently infested in Australia, South Africa, and Spain.

31. PERSIMMON (*Diospyros decandra*).

The brown persimmon (*Diospyros decandra*) is the only *Diospyros* grown in Hawaii. Mr. G. P. Wilder has grown fruits a few of which have become infested on reaching maturity. From one ripe fruit 57 adults were reared during December, 1911, by the Hawaiian Board of Agriculture. The persimmon has been reported infested from Algeria, South Africa, and Australia.

32. LOQUAT (*Eriobotrya japonica*).

The loquat (*Eriobotrya japonica*) is badly infested in Hawaii, and appears to be a favored host. Infested loquats often hang on the tree and shrivel up after the larvæ have become full grown and dropped to the ground. When punctured before the fruits are ripe, the areas about the punctures remain green after the rest of the fruit turns yellow, thus making these infestations very evident. As many as 11 punctures have been counted in a single fruit. From lots of 200 and 150 fruits each, 1,261 and 990 adults, respectively, were reared. From one cluster of 17 fruits 458 adults, or an average of about 27 flies per fruit, were reared.

In Bermuda the loquats are badly infested and serve as a host by means of which large numbers of flies pass the winter and spring months.

33. BRAZILIAN PLUM OR SPANISH CHERRY (*Eugenia brasiliensis*).

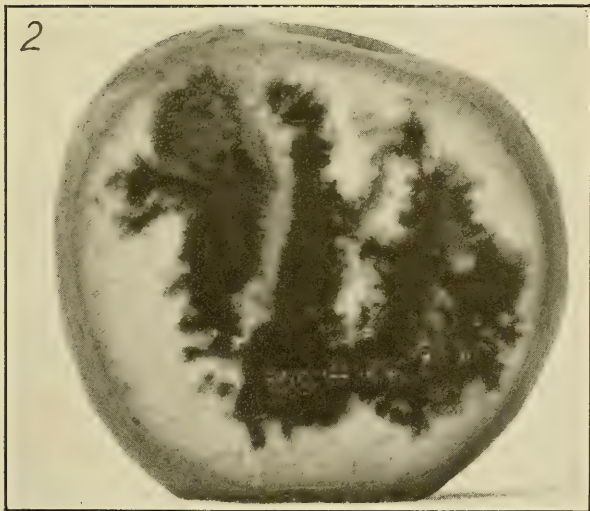
The Brazilian plum or Spanish cherry (*Eugenia brasiliensis*) is easily and badly infested. It is doubtful if a single fruit comes to maturity in Honolulu without becoming at least partially infested. The larvæ develop well in this fruit and often as many as 20 adults may be reared from a single fruit slightly over one-half inch in diameter.

34. ROSE APPLE (*Eugenia jambos*).

The rose apple (*Eugenia jambos*) (Pl. IV, fig. 2, and Pl. VIII, fig. 1) is a preferred host and is everywhere generally and badly infested about Honolulu. From 36 fruits gathered during July, 1913, in Manoa Valley there emerged a total of 1,688 adults, or an average of about 47 per fruit. Each fruit yielded adults, 10 fruits yielding 53, 6, 91, 36, 44, 58, 1, 18, 56, and 92, respectively. A total of 1,395 adults, or an average of 19.6, were reared from 75 fruits collected in Nuuanu Valley during March, 1914. One fruit from Kalihi Valley in July, 1913, yielded 20 adults.

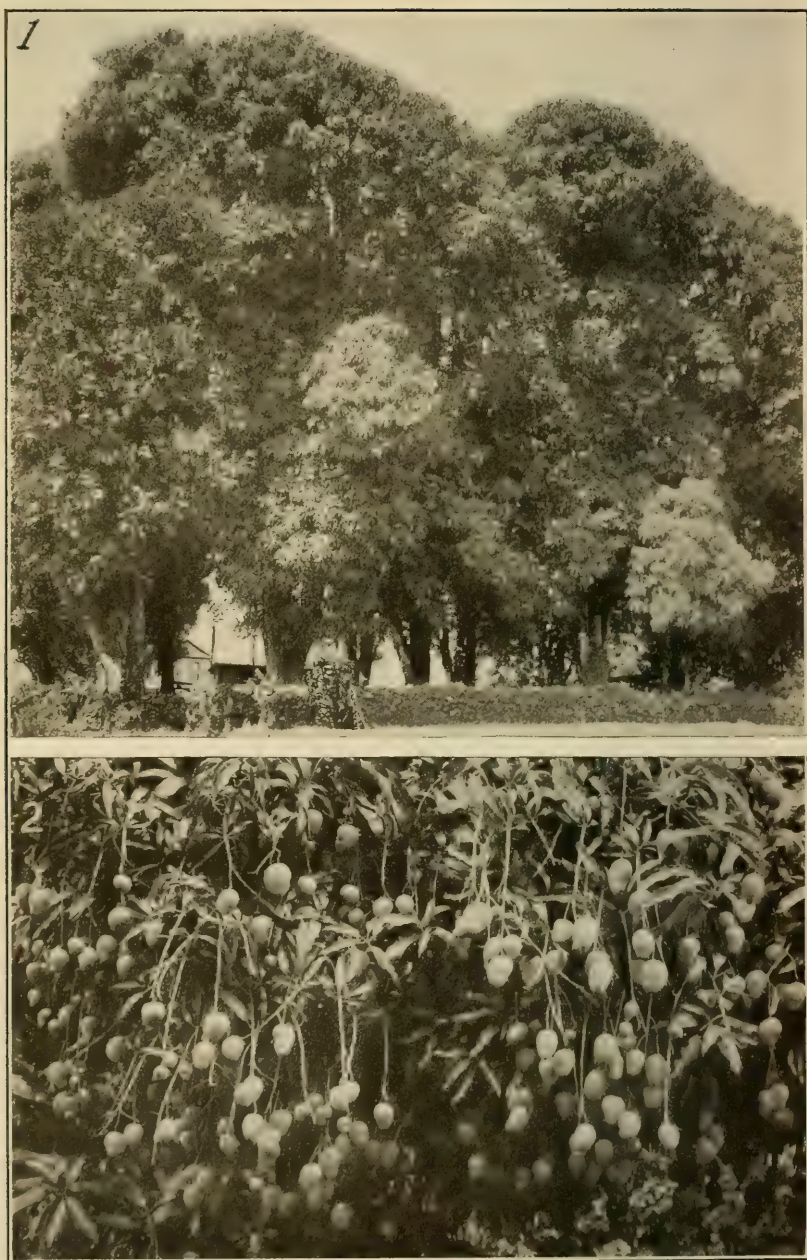
35, 36. SURINAM CHERRY (*Eugenia michelii*) AND FRENCH CHERRY (*Eugenia uniflora*).

The Surinam cherry (*Eugenia michelii*) and the French cherry (*Eugenia uniflora*), known in Spanish countries by the general term "pitangas," are fruits very generally infested, and although they never yield many adult flies in proportion to their size, very few fruits escape attack. In Bermuda the former was found to be one of the principal hosts of *C. capitata*. From 437 supposedly badly infested fruits gathered



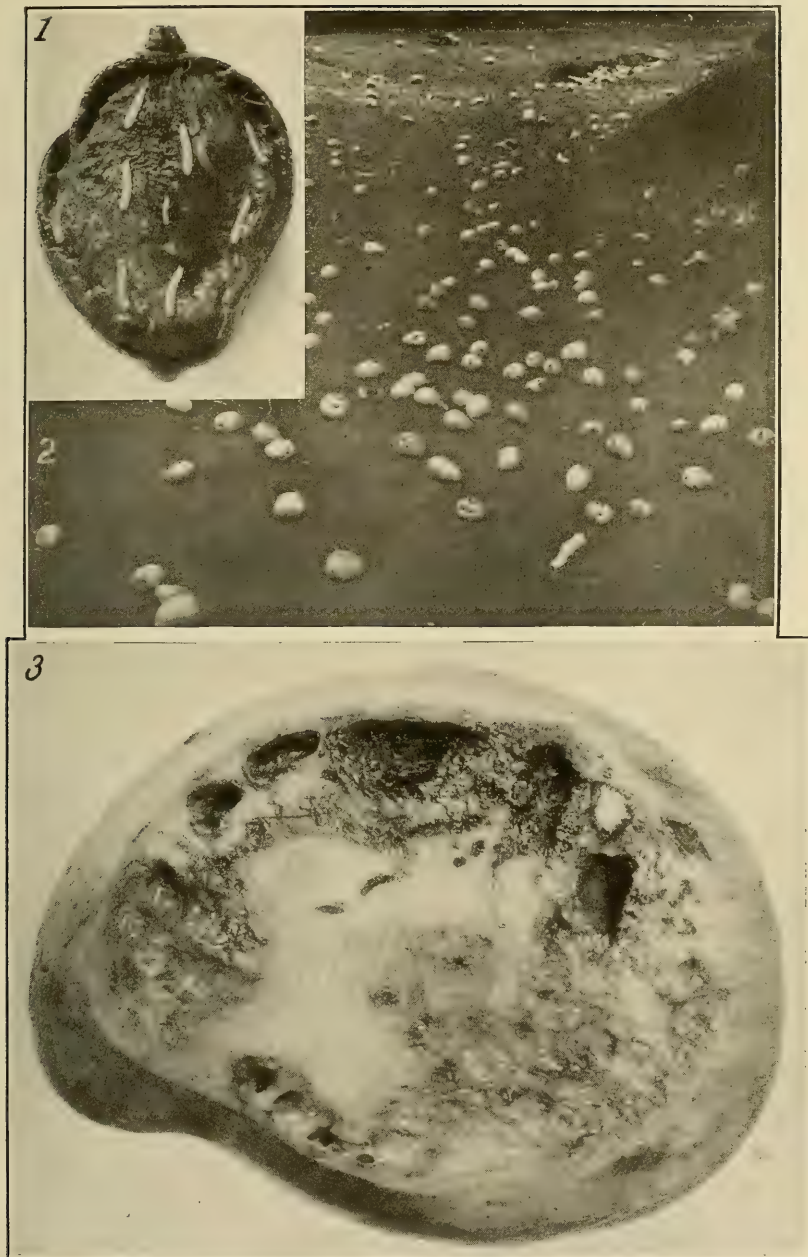
HOSTS OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—The Mediterranean fruit fly attacks cotton bolls about the time they are nearly full grown. This attack, however, appears to be of a secondary nature and follows that of the pink bollworm (*Pectinophora gossypiella*). As many as 10 well-grown larvæ have been removed from a single boll. FIG. 2.—Cross section of an apple (*Pyrus malus*) showing the destruction caused by feeding larvæ of the Mediterranean fruit fly. (Original.)



THE MANGO AS A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

Mango trees may become very large (fig. 1) and bear enormous crops of fruit (fig. 2), which, when ripening and falling, present impossible conditions for the fruit-fly inspector. (Original.)



THE MANGO AS A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Larvæ of the Mediterranean fruit fly, about natural size, in infested mango. FIG. 2.—No matter how diligently clean-culture inspectors gather fruit during the mango season, each day finds the ground beneath the trees well strewn with fallen infested fruits. FIG. 3.—Infested fruit about natural size. Note large cavity in upper right side containing several hundred white eggs. (Fig. 1, from Severin; figs. 2 and 3, original.)

during July, 1913, only 191 adults were reared. Of 45 fruits gathered during February, 1916, only 29 were infested. These 29 fruits yielded 55 adults, or an average of about 2 per fruit. Seven is the largest number of adults reared from any one of 16 infested fruits during April, 1913.

37. FIG (*Ficus carica*).

The fig (*Ficus carica*) is very generally infested. Because of the white, sticky sap which exudes copiously from abrasions made in its skin it does not become infested until the fruits are sufficiently ripe for the market. The larvæ are very small, as a rule, when the fruits are offered for sale and because of the interior structure of the fruit are easily overlooked. Only 6 out of 24 very ripe figs purchased in the market during July produced a total of 9 adult flies. Of ripe fruits purchased during March, 6 out of 22 produced 34 adults. From 12 apparently perfect figs, purchased during June, 36 adults were reared. Of 44 figs sufficiently ripe that little sap ran when they were gathered from trees in Manoa Valley, 10 proved to be uninfested. From the remaining 34 fruits 430 adults were reared, 12, 25, 28, 32, 44, and 48 adults being reared from 5 individual fruits. Kirk records rearing 241 adults from 7 figs imported into New Zealand from Australia.

38, 39. MANGOSTEENS (*Garcinia mangostana* and *Garcinia xanthochymus*).

The mangosteens (*Garcinia mangostana* and *G. xanthochymus*) do not become infested until ripe. They are not preferred hosts under Hawaiian conditions. The writers have never reared more than an average of 2 adults from infested fruits. A large percentage of the fruits are uninfested.

40. COTTON (*Gossypium* spp.).

The Mediterranean fruit fly was first reared from cotton bolls (Pl. XI, fig. 1) on October 19, 1911, by E. M. Ehrhorn from bolls collected by D. B. Kuhns from trees growing on King Street, Honolulu. Numerous flies were reared during June, 1915, by August Busck from bolls collected on the U. S. Experiment Station grounds in Honolulu and at Kaneohe, Oahu. During the same month the writers found 10 out of 201 and 6 out of 174 bolls infested. In 10 bolls 32 larvæ were found, 10 larvæ being in one boll. In all cases infestation by *C. capitata* was secondary to attack by the pink bollworm, *Pectinophora gossypiella* (Saunders), and the larvæ of the fruit fly appeared to be feeding only upon the affected portions of the bolls rather than upon the cotton fiber itself.

41. MOUNTAIN APPLE (*Jambosa malaccensis*).

The mountain apple, or "ohia ai" of the Hawaiians (*Jambosa malaccensis*), is a wild tree thriving well up to 1,800 feet elevation. The trees frequently are found growing in forests (Pl. IV, fig. 1). The fruits maturing in the forests do not appear to be more than slightly, and often not at all, infested. Fruits ripening on trees within the city of Honolulu are often badly infested. All the fruits ripening during August, 1914, on a tree growing in Pauoa Valley were infested. Ehrhorn reared adult flies from fruits from Kalihi Valley during August, 1911. As a rule, the fruits from the mountains, offered for sale in Honolulu, are free from infestation.

While none of three varieties of water apples (*Jambosa* spp.), of which there are a few trees in Honolulu, have been found infested, there is no reason why they should not be infested, as they are similar in texture to *Jambosa malaccensis*.

42. BLUE PALM (*Latania löddigesii*).

One nut of 12 collected from a tree growing on Keeamaku Street, Honolulu, was found infested. Two adult flies were reared. Prof. O. H. Swezey has also reared adults from the overripe nuts of this palm.

43. TOMATO (*Lycopersicum esculentum*).

The ordinary cultivated tomato (*Lycopersicum esculentum*) is not generally infested by *C. capitata*, although many adults of *Bactrocera cucurbitae* and certain decay flies (Drosophilidae) are reared. Thus 270 ripe fruits gathered promiscuously from the market gardens of Waikiki during June, 1916, yielded no adult flies when held over sand in jars. Sixteen ripe fruits gathered from the market gardens of Moiliili on March 25, 1913, yielded the melon fly (*B. cucurbitae*). It is interesting to note that of seven lots of tomatoes collected during 1911 and early 1912 by the Hawaiian Board of Agriculture, none produced adults of *C. capitata*. That *C. capitata* may be reared in numbers from tomatoes under field conditions has been demonstrated by the ease with which adults oviposit in both ripe and green, although well-grown, fruits in the laboratory under forced conditions. Of 4 ripe tomatoes placed singly for 7 hours in jars containing about 200 adults, only one yielded 3 adults, although all 4 were oviposited in and contained on removal from the jars an average of 13 punctures. One fruit yielding no adults contained 42 punctures. From one green but well-grown fruit exposed in a jar for 7 hours with 200 adults, only 5 adults were reared. From six other ripe fruits similarly exposed in two lots of 3 each, there emerged only 16 adults; and only 5 adults developed in one lot of 3 fruits containing 29 punctures in the skin.

The currant tomato (*Solanum pimpinellifolium*), the grape tomato (*Solanum lycopersicum*), and the "popolo" tomato (*Solanum nodiflorum*) have never been found infested. Newman writes that *C. capitata* has often been reported infesting tomatoes and other *Solanum* species, but that he had never reared from them any fly in Western Australia but *Lonchaea splendida* Loew, the tomato fruit fly—a fly which does not occur in Hawaii.

44. LICHEE NUT (*Litchi chinensis*).

The lichee nut (*Litchi chinensis*) is not infested so long as the fruits remain perfect. The shell-like covering of the fruits often splits as the fruit reaches maturity, and in the pulp thus exposed the adult can, and has been known to, deposit eggs. Several split fruits were found infested during September, 1913. One depauperized adult was reared by the Hawaiian Board of Agriculture from a split fruit during July, 1912. It is possible for infestation to occur in fruits infested by the tortricid *Cryptophlebia illepidata* Btl. Seven ripe fruits, freshly picked and sound in every way, were hung in jars of adult flies for a two-day period during June, 1915. An examination of them after their removal proved that the flies had not been able to puncture the shell.

45. MANGO (Plates XII, XIII).

The mango (*Mangifera indica*) is a favorite host of the fruit fly. In Hawaii the common seedling varieties are so badly attacked that many owners are willing to have the crops removed and destroyed before they ripen. Twelve fruits picked from the ground in upper Manoa Valley yielded 313 adults, 95 adults emerging from one fruit. Of a total of 47 fruits from the same locality taken from the ground on July 27, 25 yielded 423 adults. Sixteen of 33 fruits taken from the ground at the Hawaiian Church, Manoa Valley, yielded no adults, but 502 were reared from the remaining 17 fruits. Of fruits taken from the ground on the Cooper estate, Manoa Valley, 26 of 35 yielded 527 adults during August. These records are fair samples of the infestation of seedling sweet mangoes in the outlying districts of Honolulu, where there are many wild guavas bushes.

The mango is one of the fruits subject to attack which becomes infested only as it ripens. Up to that time it is quite well protected from attack by the copious exudations of distasteful sap which follow attempts at oviposition. Often where the combined attack of the mango weevil (*Cryptorhynchus mangiferae* Fab.) and fruit-fly adults is severe the fruits are well stained with the exuded sap. It has been the experience of the writers that very few adults can be reared from hard well-grown fruits picked from or beneath trees on which many fruits are ripening and falling to the ground,

even where they show many indications of attempted oviposition. Thus from a total of 292 such fruits representing 12 lots collected from the ground in Pauoa Valley, Moanalua Gardens, and Nuuanuu Valley, during July and August, only 6 adults were reared. The thicker the skin of the fruit the more difficulty does the adult have in ovipositing successfully.

TABLE XI.—*Varietal susceptibility of mangoes to the attack of the Mediterranean fruit fly under forced conditions.*¹

Combination of varieties.	Number of—		Combination of varieties.	Number of—		Combination of varieties.	Number of—	
	Punc-tures.	Eggs.		Punc-tures.	Eggs.		Punc-tures.	Eggs.
Common mango	48	327	Strawberry.....	16	139	Common man-		
Cambodiana.....	8	61	Wood chutney..	11	129	go ⁴	0	0
Brinda Bani....	0	0	Brinda Bani....	0	0	Jamshedi ⁴	0	0
Oahu.....	3	42	Common mango	14	129	Divine ⁴	0	0
Piri.....	0	0	Oahu.....	23	249	No. 1928.....	1	9
Brinda Bani....	0	0	Totofori.....	0	0	Alphonse.....	0	0
Common mango	8	73	No. 1928.....	3	18	Brinda Bani....	0	0
Wood chutney ²	60	584	Samoa chut-			Common mango	28	370
Samoa chut-			ney.....	29	291	Oahu.....	5	59
ney ²	12	138	Brinda Bani....	0	0	Brinda Bani....	0	0
Common mango	5	52	Common mango	20	223	Common mango	13	139
Cambodiana.....	9	86	Wooten chut-			Strawberry ³ ...	25	178
Wooten chut-			ney.....	25	403	Brinda Bani....	0	0
ney.....	10	115	Totofori.....	7	43	Wooten chut-		
Common mango	40	293	No. 1928.....	0	0	ney ⁴	0	0
Cambodiana.....	0	0	Piri.....	0	0	Wooten chut-		
(hard).....	0	0	Wood chutney..	8	112	ney ²	5	38
Cambodiana.....	18	182	Piri (hard).....	2	11	Common mango	23	441
Common mango	15	111	Piri (slightly			Cambodiana.....	0	0
Strawberry.....	8	91	soft).....	21	196	Brinda Bani....	0	0
Brinda Bani....	0	0	Divine.....	0	0	Common man-		
Strawberry.....	15	206	Strawberry.....	1	5	go ⁴	6	53
Seedling No.			Jamshedi.....	0	0	Jamshedi ⁴	0	0
1928.....	3	32	Strawberry ³ ...	14	132	Strawberry ³ ...	45	481
Brinda Bani....	0	0	No. 1928.....	4	42	Common man-		
Divine.....	0	0	Brinda Bani....	0	0	go ³	29	196
Wooten chut-			Common man-			Piri ³	2	14
ney ²	44	314	go ³	4	35	Piri (hard)....	0	0
Brinda Bani....	0	0	Oahu ³	5	38	Common man-		
Piri.....	1	68	Totofori ³	7	40	go ⁴	1	11
Jamshedi.....	0	0	Common mango	5	60	Cambodiana ⁴ ...	0	0
Divine.....	0	0	Wooten chut-			Wooten chut-		
Wooten chut-			ney.....	24	272	ney ²	19	101
ney ²	6	27	Totofori.....	0	0	Wooten chut-		
No. 1928 ³	4	28				ney.....	6	41
Cambodiana ³ ...	8	93				Divine.....	0	0
						Brinda Bani....	0	0

¹ Unless otherwise noted, the fruits used in each experiment were equally hard, though fully matured and from trees on which fruits had already begun to ripen.

² Less hard than the common mango.

³ Soft.

⁴ Very hard.

⁵ Slightly softer than other two fruits.

While the common thin-skinned sweet mangoes are badly infested when they ripen, many chutney mangoes and certain highly developed horticultural varieties of eating mangoes are less susceptible to attack, owing, in the one instance, apparently to a greater amount of "turpentine" in the skin, and, in the other, to a much thicker skin. Under forced conditions adults will oviposit heavily in chutney mangoes which, ripening on the tree, escape infestation. Three fruits of a "Chinese" chutney-variety¹

¹ For purpose of future identification it may be stated that one tree of this variety is grown by Mr. G. P. Wilder, of Honolulu.

said to be free from attack were exposed to adults in the laboratory and 219, 285, and 222 eggs, respectively, were laid in them. To determine whether the confinement of different varieties of improved mangoes would throw any light upon their varietal susceptibility, the various combinations indicated in Table XI were placed in jars of ovipositing adults and allowed to remain 24 hours. This experiment was made possible by the gift by the Federal Experiment Station at Honolulu of fruits which had been protected from fruit-fly attack by paper bags. The extent of infestation under these forced conditions shows that the Piri, Brinda Bani, and Divine were least affected. The Divine and Brinda Bani are varieties so little attacked in the open that they are not protected by paper bags during development. It is interesting to note that the Piri, which is one of the very best eating varieties of mangoes grown in Honolulu, is the least susceptible to attack of the varieties used in the experiments with the exception of the Brinda Bani and Divine. The Black Alfonse and Cowasjee Patel grown at the Moanalua Gardens appear equally resistant with the Piri, and from these gardens Mr. S. M. Damon has sent out many superb fruits of these three varieties, which reach maturity uninfested and unprotected.

46. ELENGI TREE (*Mimusops elengi*).

The fruits of *Mimusops elengi* grown in Hawaii appear to belong to two varieties. Both are infested as they become fully ripe, but the glabrous variety supports many more larvæ than the pubescent variety (Pl. VIII, fig. 2). The fruits of both have a tough, firm outer shell, a mealy pulp, a proportionally large central stone, and are about three-fourths of an inch long. Of 34 fruits of the glabrous variety gathered from the ground during February only 7 yielded no adults. From the remaining 27 fruits, 355 adults, or an average of about 13 adults per fruit, were reared. Of 15 fruits of the pubescent variety gathered from the ground at the same time, 8 yielded no adults, and 7 yielded 27 adults. From 10 fruits of the glabrous variety 17, 15, 13, 19, 7, 30, 21, 22, 19, and 2 adults were reared.

47. MOCK ORANGE (*Murraya exotica*).

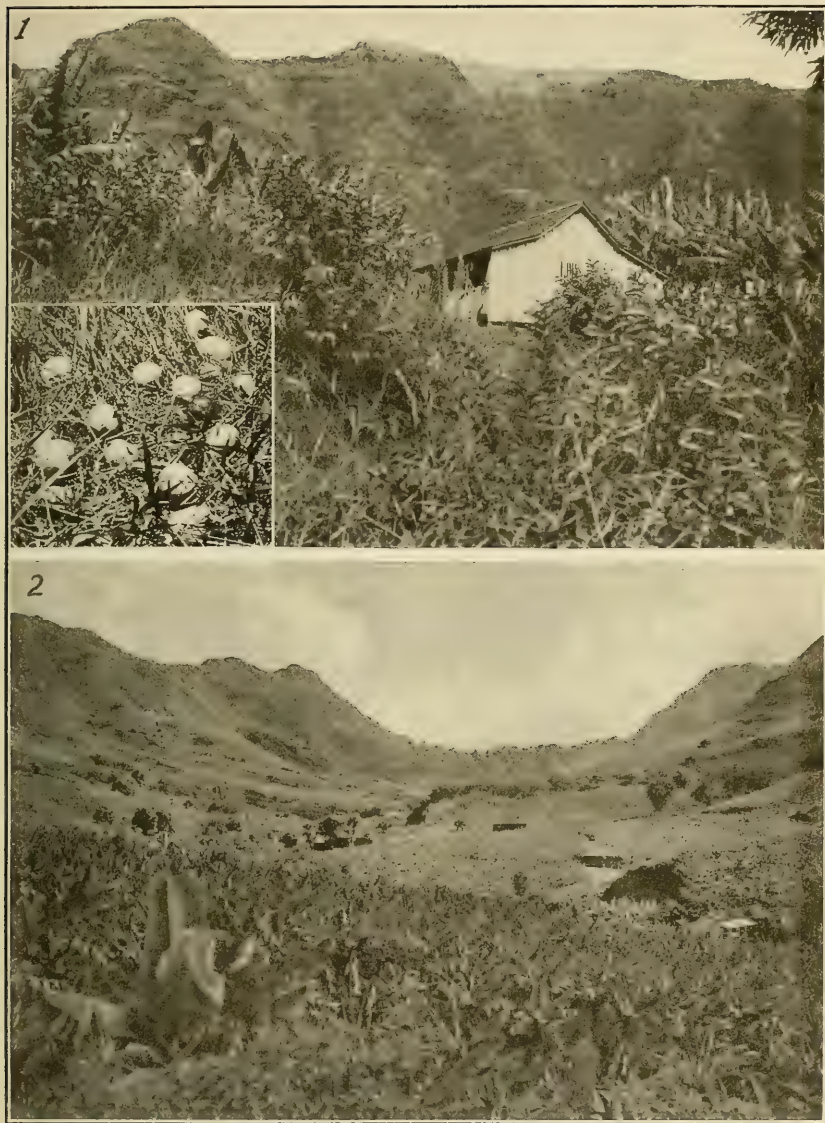
The small fruits of the mock orange or orange jessamine (*Murraya exotica*) are preferred hosts (Pl. VIII, fig. 4). From 1 to 3 larvæ only are able to mature in a single fruit. Of 111 fruits gathered during March, 1914, 26 were not infested. From the remaining 85 fruits 148 adults were reared; 10 fruits yielding, respectively, 1, 1, 2, 3, 2, 1, 1, 2, 1, and 3 adults.

48. BANANA (Pl. XIV, XV, XVI).

The banana export trade of the Hawaiian Islands amounted to 256,319 bunches during the year ended June 30, 1915. For the most part, the shipments were composed of the chief commercial variety of Hawaii, the Chinese banana (*Musa cavendishii*), although a small number of Bluefields (*Musa sapientum*) entered into the shipments. With the appearance of *C. capitata* in Hawaii, it became imperative, therefore, to determine to what extent, if any, this established trade jeopardized the mainland fruit interests. Previous to the experimental work in Hawaii, the banana had been classed among the host fruits of *C. capitata* by officials of the Australian Commonwealth and by Gowdey¹ of British East Africa without modifying statements.

A critical review of the Australian literature seems to indicate that the positive references to the presence of *C. capitata* in bananas should be questioned, as it is more than probable that the similarity in the appearance of fruit-fly larvæ has led to a con-

¹ In a letter to the writers dated July, 1916, Gowdey writes that his previously reported rearing of *C. capitata* from bananas was made under abnormal or laboratory conditions. He succeeded in rearing adults from overripe bananas infested in the laboratory. He was not attempting to prove the immunity, or otherwise, of this fruit when green, although sufficiently ripe for the trade, and makes no claim that under field conditions the banana is a host fruit of this fly.



REGULATING MEDITERRANEAN FRUIT-FLY CONDITIONS.

As a result of the regulation of the Federal Horticultural Board the unsanitary fruit-fly conditions about banana plantations have been corrected. FIG. 1.—A small Chinese banana plantation. At present, such guava bushes as are shown, and all other host plants about or in plantation from which fruit is shipped, are cut sufficiently often to prevent fruiting, thus removing the opportunity for fruit-fly larvae emerging from fallen fruit (see insert) to become attached as pupæ to wrapping material and be transported to California. FIG. 2.—General surroundings of small banana plantations in Kalihi Valley, Oahu, from which fruit is shipped to California. The fruit fly is thoroughly entrenched on all the mountain slopes. (Original.)



THE MEDITERRANEAN FRUIT FLY AND THE BANANA INDUSTRY.

FIG. 1.—Typical Chinese house and packing shed at small banana plantations. The rice straw and dried banana leaves used for wrapping all export fruit are stored in open sheds similar to one illustrated to left of view. FIG. 2.—In a bluefield banana plantation at Hilo. Note the dead dried leaves hanging to the trees; when these are thoroughly dry they are cut and stored for wrapping export fruits. (Original.)



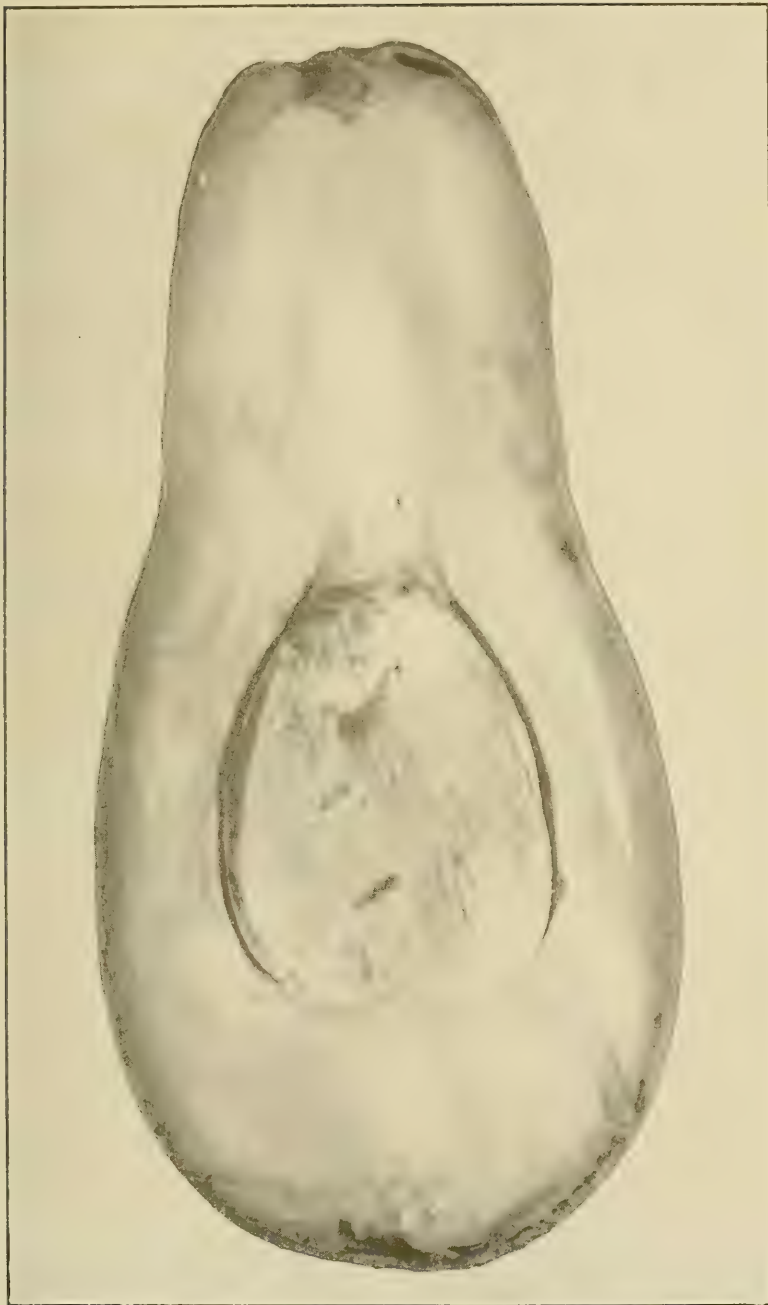
THE MEDITERRANEAN FRUIT FLY AND THE BANANA INDUSTRY.

FIG. 1.—Rice straw stacked in the open to be used as wrapping material for export bananas. FIG. 2.—Chinese bananas cut and cleaned, waiting inspection by officer of Federal Horticultural Board. FIG. 3.—Chinamen remove all split, overripe, and bruised fruits as the bananas are brought to the packing sheds from the field. Each bunch is thus cleaned previous to inspection as a safeguard to mainland interests. (Original.)



THE PRICKLY PEAR AS A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—Heavily fruiting plant growing on dry arid and waste lands of the Island of Hawaii. In many places this wild host, with the spiny *Acacia*, forms dense thickets in which the fruit fly can breed. FIG. 2.—A sample of dense growth of prickly pear along the road near Kailua, Hawaii. The seed pods of the algaroba tree (*Prosopis juliflora*) are not infested. (Original.)



THE AVOCADO OR ALLIGATOR PEAR AS A HOST OF THE MEDITERRANEAN FRUIT FLY.

Cross section of improved fruit. Note slight infestation at stem and blossom ends. Infestation is not always general and usually does not interfere with local consumption. The slight infestations, however, have forced this fruit into the quarantine list, thereby ruining a profitable and growing export trade. (Original.)

fusion of other fruit-fly species, known definitely to attack bananas, with *C. capitata*. Illingworth, in 1913, reared the banana fruit fly (*Dacus curvipennis* Frogg.) from larvæ taken in Sydney from bananas imported from Suva. Lea, in Tasmania in 1908, thoroughly familiar with the Mediterranean fruit fly as a result of the campaign for its eradication about Launceston, states that the Queensland fruit fly (*Dacus tryoni* Frogg.) only was found in bananas imported into Tasmania, and does not list this fruit among the host fruits of *C. capitata*. Broun states that, in 1906, *Dacus tryoni* was the only fruit fly reared from bananas imported during February and March into New Zealand from Fiji and Rarotonga. In the report of the biologist of Western Australia in 1898 we read that a consignment of 50 cases of bananas supposed to have originated in Fiji, but more likely having been transhipped to Sydney from an original source in Queensland, had been destroyed at Freemantle because found infested by the Queensland fruit fly. Quinn, in 1907, writes "after seven years experience with bananas * * * we have not yet found the maggots in green bananas. If green when arriving here (South Australia), how very green indeed must they have been when cut from the trees about three weeks previous." French, of Victoria, appears to be the only person in Australia who definitely makes the statement that he has reared *C. capitata* from bananas exported from Queensland into Victoria. Yet Tryon, of Queensland, in a conversation with the senior writer in 1913, stated that *C. capitata* had never been taken in the banana fields of Queensland. The inclusion of the banana among the fruits infested by *C. capitata* and intercepted at the entry ports of New Zealand by Kirk seems to have been an editorial error, as already pointed out in the paper on the banana as a host referred to below. From the foregoing references, it is possible to assume that the results obtained by the writers in Hawaii, where fruit-fly attack is as severe as anywhere, will be verified when opportunity is presented for such careful experiments in other countries as the commercial value of this fruit warrants. Because of the controversial statements of French and Severin it is desirable that Australian entomologists publish data secured in field experiments.

Those particularly interested in the status of the banana as a host fruit are referred to a paper¹ already published by the writers, giving experimental data from which the following conclusions were drawn:

Since the Mediterranean fruit fly (*Ceratitis capitata* Wied.) has not been found infesting the Chinese banana (*Musa cavendishii*) or the Bluefield banana (*Musa* sp.) during the three years that the Federal Government has had charge of the inspection of export bananas in the Hawaiian Islands, it is evident that some reason exists for this practical immunity. This is the more apparent since adult flies of both sexes have been found present in all parts of banana plantations, and surrounding fruits known to be hosts have been heavily infested.

This immunity is shown to be due to the fact that neither the egg nor the nearly hatched larva of the fruit fly can survive in the tannin-laden peel of green, though mature, fruit. In fact, the copious and sudden flow of sap from egg punctures made by fruit flies in unripe bananas renders the successful deposition of eggs in such fruits difficult and rare.

The fact that not 1 of 1,044 fruits of the Chinese banana ripening singly and prematurely among bunches growing in the field, and upon which, as in the case of other host fruits, one might expect gravid females to concentrate their attention for the purpose of oviposition, has been found to be infested, leads to the conclusion that even ripe bananas are not desired as host fruits by adult fruit flies under Hawaiian conditions. On the other hand, the rearing of flies from the ripe and yellow fruits of the thin-skinned Popoulu variety, as well as from ripe fruits of other varieties under forced and unnatural conditions, leads to the equally acknowledged fact that ripe bananas in the field may serve as hosts and should therefore be properly guarded against in all quarantine work.

From the facts stated, the writers believe that bunches of any variety of bananas² now growing in the Hawaiian Islands, when properly inspected for the removal of

¹ Back, E. A., and Pemberton, C. E. Banana as a host fruit of the Mediterranean fruit fly. Jour. Agr. Research, v. 5, p. 793-804. 1916.

² As an added precaution against the spread of *C. capitata* to the mainland, cooking bananas of all types are excluded from the trade.

prematurely ripe, cracked, or partially decayed fruits, offer no danger as carriers of the Mediterranean fruit fly, provided they are wrapped and shipped in accordance with the demands of the trade and the Federal regulations.

In addition to the data already presented by the writers, on the immunity of bananas during a 10-day period after the fruit is sufficiently mature for shipment during the summer months, other experimental work has been carried out by H. F. Willard under the writer's direction. This experimental work in detail emphasizes so well the immunity of well-grown bananas still attached to the tree but green in color, although many fruits on the same bunch have either cracked or ripened, that portions of the data are given herewith. The hands of fruit are numbered from the stem end of the bunch.

On November 30, 1915, 14 bunches of Chinese bananas marked in the field at Moiliili for shipment within two days to California were requisitioned and held uncut for experimental work to determine how long during the winter months the bunches could hang after they were sufficiently ripe for the export trade and still ward off attack. A wire-screen cage containing 300 adult flies was placed over one bunch December 13-15, and three days after its removal an examination of the 131 fruits on the bunch, all green in color, showed 108 fruits to be free from attack. Of those attacked 20, 1, and 1 had respectively, 3, 1, and 4 punctures, all of which contained no eggs and were more or less superficial; a single puncture in the remaining fruit contained two living first-stage larvæ which later died.

A second bunch from which there had been cut on December 22 1 sound yellow fruit, on December 27, 2 sound and 2 cracked yellow fruits, and on December 29, 3 cracked yellow fruits, was caged on the last date with 300 adults. On December 31, or one month after the fruit was sufficiently ripe for shipment, the cage was removed and on January 3 examined with the following results:

Hand 1: 13 fruits; 7 green and puncture free. Six yellow, 2 puncture free; 1, 1, and 2 had, respectively, 4, 2, and 1 empty punctures.

Hand 2: 15 fruits; 10 green and puncture free. Five yellow, 2, 1, 1, and 1 had 0, 2, 1, and 9 punctures. Punctures empty but ones which contained 2 first stage larvæ that soon died.

Hand 3: 15 green puncture-free fruits.

Hand 4: 14 green fruits; 12 puncture free, 2 had 1 empty puncture each.

Hand 5: 9 green fruits; 7 puncture free, 2 had 1 empty puncture each.

Hand 6: 12 green fruits; 11 puncture free, 1 had 1 empty puncture.

Hand 7: 14 green fruits; 13 puncture free. One fruit had been bruised, so that it was yellow and had begun to decay on one side; it had 7 punctures, of which 2, 2, 1, and 2 contained 6, 1, 4, and 0 eggs, respectively. From this fruit 4 adult flies were reared.

Hand 8: 7 green fruits; 5 puncture free, 1 with 3 empty punctures, and 1 with 1 empty and 3 dead and 1 living first-instar larvæ. Living larvæ died in puncture.

A third of the bunches marked November 10 was caged with 300 adults on January 5, after 43 yellow bananas had been cut from the bunch. On January 7 the cage was removed and the bunch cut. An examination made on January 11 gave the following results:

Hands 1 and 2: Fruits had ripened and been cut before caging.

Hand 3: 4 yellow fruits, 3 puncture free. Remaining fruit had 2 punctures with eggs and eggshells. No adults were reared though the fruit was held over sand.

Hand 4: 8 yellow fruits, 5 puncture free; 1, 1, and 1 fruits had 3, 1, and 1 empty punctures.

Hand 5: 12 yellow fruits, 9 puncture free; 1, 1, and 1 had 3, 2, and 1 empty punctures, respectively.

Hand 6: 13 fruits, 12 green and 1 yellow; no punctures.

Hand 7: 12 green fruits, 11 puncture free; 1 had 2 empty punctures.

Hand 8: 11 green fruits, 9 puncture free; 2 had 1 empty puncture each.

The results of the foregoing experiments, together with others on file, strengthen the conclusions quoted above that bananas cut, wrapped, and shipped according to trade and Federal regulations are not a source of danger as carriers of *C. capitata*. Particular attention is called to the very slight infestation secured under forced conditions, even among fruits actually turning yellow on the tree. Many hundred adults would have been reared from favored host fruits similarly caged with adults.

49. *Noronhia emarginata*.

Noronhia emarginata is a native fruit of Madagascar and Mauritius. The writers have never found it infested, but Mr. E. M. Ehrhorn reared 24 adults from a sample of fruit during July, 1912. Mr. Ehrhorn is also authority for the rearing of adults from fruits grown on Kauai.

50. *Ochrosia elliptica*.

The shrub *Ochrosia elliptica* is grown because of the ornamental value of its scarlet fruits. These are occasionally infested. Thirty adult flies were reared from one lot of 12 fruits maturing in the Punahou district of Honolulu, and 8 from one fruit grown at Waikiki.

51. PRICKLY PEAR (*Opuntia vulgaris*).

Although the prickly pear (*Opuntia vulgaris*) grows wild (Pl. XVII) on waste arid lands in Hawaii, it is not a preferred host. From 23 overripe fruits taken from the ground during August, 1912, on Punchbowl, only 15 flies were reared, while no flies were reared from 28 similar fruits gathered at the same time. No flies were reared from 29 lots totaling 254 fruits collected in Pauoa, Palola, Makiki, Moanalua, and Kalauao during September-December, 1912. These fruits were all ripe, many too ripe to remain erect on the plant, and some had fallen to the ground. From 8 fruits ripe, but erect on the plant, cut from plants on Punchbowl close to the Federal Experiment Station, 8 flies were reared; 10 fruits taken from the ground near the top of Punchbowl at the same time (September, 1912) yielding only 1 fly. Of 8 lots of ripe fruits gathered from plants during December, 1914, from Ewa, Fort Shafter, Kalauao, Red Hill, Salt Lake Road, upper and lower Palolo and Manoa Valleys, totaling 118 fruits, only 1 lot of 5 fruits from Ewa yielded 2 adults.

Compere reports the prickly pear about Malaga, Spain, to be infested by *C. capitata*.

52. PASSION VINE (*Passiflora coerulea*).

The fruits of only one species (*Passiflora coerulea*) of passion vines have been found infested by *C. capitata* in Hawaii. Infestation is by no means severe. At Haiku, island of Maui, a search among several hundred ripe fruits proved only two fruits to have been infested, and from these six adults were reared. While numerous fruits of different sizes have been found deformed by punctures on Oahu no adult flies have been reared. It is doubtful if this passion vine supports *C. capitata* except when growing luxuriantly in shaded localities.

Fruits of *Passiflora quadrangularis*, *edulis*, *laurifolia*, *alata* and *foetida* have not been found infested. The common water lemon (*P. laurifolia*) found upon the markets of Hawaii is impervious to attack when ripe, as proved by hanging fruits in jars of adult flies.

53. AVOCADO (*Persea gratissima*).

The avocado (*Persea gratissima*), palta, or alligator pear as it is sometimes called (Pl. XVIII), is one of the host fruits of *C. capitata* that become infested, if at all, late in their development. In fact, the nature of its infestation for most horticultural varieties is so obscure that the general belief prevails that avocados are free from attack. Previous to the introduction of *C. capitata* in Hawaii a small and growing export trade was being developed and, because of the excellence of the improved Hawaiian avocado,

it promised to become a financial asset to the islands. Even since the quarantines of the Federal Horticultural Board stopped shipments of avocados to the mainland of the United States shipments have been made to the Philippine Islands in cold storage. The following data are the first ever published on the infestation of avocados and are given here to refute arguments for reestablishing the avocado trade on its former basis:

There are many horticultural varieties of the avocado growing in Hawaii, but there appears to be little difference in their degree of susceptibility to attack. The nutmeg or Guatemala variety is the only one free from attack when growing uninjured. Under forced laboratory conditions adults can not oviposit through its unusually thick rind. The skin of all other varieties of avocados, whether very thin or of usual toughness, can be punctured by the adult fly, as proved by the examination of many fruits. The avocado, like the ordinary pear, is best if picked when still hard and allowed to ripen in storage.

If left on the tree too long, the fruits drop and soften on the ground. With most varieties it is not until the fruits are mature enough for gathering or dropping that adults oviposit in them. As they are sufficiently soft for eating purposes within two to four days after being cut from the tree, the larvæ are still very young, if not just hatched, and are to be found feeding close to the tough leathery rind. Their presence, therefore, is seldom observed by those eating avocados served whole or cut in half to be eaten with a spoon. When served cut in small pieces, with mayonnaise, the paring process usually crushes the small larval burrows on the outer surface of the pulp and the larvæ go to the table unobserved. As thousands of larvæ are thus consumed yearly in Honolulu alone, it may be well to state that they do no harm.¹ Fruits in which the larvæ have become well grown are usually too soft for eating purposes.

Several thousand fruits have been examined carefully by the removal of the skin. Of 1,027 fruits thus examined, picked from the trees at Wahiawa and representing 10 separate lots of fruit, 173, or 16.8 per cent, were found to contain eggs or larvæ; of 384, representing six lots of fruit picked from the ground at Wahiawa, 57 fruits, or 14.8 per cent, were infested. Notes on certain uninfested fruits show that of the green varieties 354 were thick skinned and 75 were thin skinned; of the purple varieties, 254 were thick skinned and 101 were thin skinned. Of 120 infested fruits, 42 and 12 were green varieties with thick and thin skins, respectively, while of the purple varieties, 32 and 34 were thick skinned and thin skinned, respectively. The considerably larger proportion of thin-skinned purple fruits found infested agrees in the main with observations on similar fruits found on the markets. Eleven purple fruits of an early thin-skinned variety picked from the tree in the Makiki district of Honolulu had an average of over 41 punctures in the skin, no fruit having less than 12 or more than 119 punctures. A fruit of a second thin-skinned purple variety grown by Mr. G. P. Wilder, of Honolulu, known to be generally infested if the fruits are allowed to remain on the tree too long, was hung in a jar of adult flies for about 18 hours beside a fruit similar in appearance and degree of ripeness, taken from another tree. An examination after removal of the fruits showed 7 eggs to have been deposited in 1 puncture in 1 fruit while in the Wilder fruit 487 eggs had been deposited in 56 punctures. In a green fruit with a hard, tough skin exposed to adults for 5 hours, 32 eggs were deposited in 14 punctures. One lot of 863 fruits of all varieties gathered by a fruit dealer from trees in upper Manoa Valley and the Punahou district of Honolulu were not infested, but these were picked several days earlier than they might have been picked. Avocados shipped rather green from the islands of Hawaii and Kauai to Honolulu (Oahu) were not found infested, but their freedom from infestation was due to the earliness of their gathering. Ten thin-skinned purple fruits grown at Waikiki and purchased in the market had an average of over 9 punctures per fruit, 1 fruit having 33 punctures and

¹ The writers have personally conducted experiments in which it is estimated persons have eaten 2,000 eggs and young larvæ in plums without injurious results.

only 1 being puncture free. Ten thick-skinned green fruits in the market from Kalauao had an average of 6.2 punctures, with no fruit puncture free; 4 of 6 thin-skinned purple fruits taken from the market were puncture free, the remaining 2 fruits having 1 and 3 punctures, respectively. One thick-skinned green fruit picked by the owner and brought to the laboratory as an example of a fine fly-proof variety was found when examined in his presence to contain 230 eggs in 18 punctures. The details of the examinations of many hundred individual fruits are on file and open to those desiring further information on the infestation of avocados at the time they are offered for sale.

In spite of the frequency of infestation as indicated above, the avocado does not appear to be a very satisfactory host for *C. capitata* when one considers its relatively large size and the number of adult flies that can be reared from it. The larval mortality is greater than in many preferred hosts. From thin-skinned purple fruits containing 119, 41, 29, 19, and 37 punctures, 4, 7, 39, 6, and 0 adults were reared. Only 36 adults were reared from a green-skinned variety known to have contained 230 eggs. From 1 fruit that had begun to wither on the tree, an unusual occurrence, 16 adults were reared. Forty-eight is the largest number of adults ever reared from a single fruit by the writers. Of 81 fruits of all varieties known to have been infested when placed separately in jars over sand, 39 produced no adults, while from the remaining 42 fruits 570 adults were reared. No adults were reared from 427 fruits gathered promiscuously and placed in jars without examination to prove them infested.

54. DATE PALM (*Phoenix dactylifera*).

Although thousands of fruits of the unimproved date palm (*Phoenix dactylifera*) ripen each year in Hawaii, the writers have found only one instance of infestation. Thirty-five green, but well-grown, dates collected August 11, 1913, at Ainahau, Waikiki, which appeared to have been affected by some disease that rendered them abnormally moist, yielded 2 adults of *C. capitata*. This was probably a chance infestation.

55. STRAWBERRY GUAVA (*Psidium cattleianum*).

The strawberry guava (*Psidium cattleianum*) is a preferred host, and the fruits are usually badly infested. From 96 out of 145 fruits picked March 16, 1913, 364 adults were reared, or an average of 3.8 per fruit. No fruit yielded more than 8 adults. From 500 fruits an average of 4.1 adults were reared during April, 1913. From 90 fruits collected during February, 1916, an average of 4.8 adults per fruit were reared; 15 fruits yielding 1, 3, 2, 11, 7, 7, 6, 5, 9, 7, 6, 2, 8, 6, and 18 adults, respectively.

56-58. GUAVAS.

The common guavas of Hawaii (*Psidium guayava*, *P. guayava pomiferum* and *P. guayava pyrifera*) are subject to general infestation. While the guava grows wild up to 4,000 feet elevation and forms dense thickets on the lower levels, even many miles from habitations (Pls. II, III), and is an ever-present source of adult flies, many statements previously published exaggerate the degree of infestation of individual fruits. The writers have never been able to collect samples of 25 miscellaneous fruits without finding some infestation; 14, 18, 15, 17, 10, 10, 10, 24, 7, 6, 6, and 6 fruits collected at 14 places on the windward and leeward sides of Oahu on September 9, 1914, yielded respectively 60, 46, 46, 107, 119, 11, 19, 4, 41, 1, and 2 adults. Each of 62 fruits, except 7, picked ripe from bushes at points along the Tantalus Road yielded adults; from 55 fruits 307 adults were reared. During January, 1916, 75 per cent of all fruits examined along the same road were found infested. From 18 fruits collected May 30, 1913, from bushes near the Libby, McNeil, and Libby Cannery, windward Oahu, at sea level, 423 adults, or an average of 23.5 flies per fruit, were reared. Nine fruits collected between Wahiawa and Haleiwa, Oahu, on January 21, 1912, yielded 96 adults. The writers have never reared more than 34 adults from a single fruit.

That it may be appreciated that, contrary to the belief of many, the wild guavas in the mountains back of Honolulu are a continual source of adult flies, particularly in midwinter, the following records were made:

- 21 fruits picked on and near the top of Round Top, Tantalus, 1,100 feet elevation, December 19, 1913, yielded 63 adults.
- 24 fruits from Pauoa Flats, 1,100 feet elevation, December 22, 1913, yielded 69 adults.
- 42 fruits from rim of Palolo Crater during December, 1913, yielded 362 adults.
- 22 fruits from top of east ridge, Manoa Valley, 1,000 feet elevation, yielded 100 adults.
- 50 fruits from head of Palolo Valley, 1,000 feet elevation, on January 2, 1914, yielded 84 adults.

59. PEACH (*Prunus persica*).

The peach (*Prunus persica*) is the most preferred of all host fruits grown in Hawaii and in other countries (fig. 3). While excellent peaches have been grown in the islands, at the present time scarcely a peach matures on the lower levels, and usually the fruits are utterly destroyed before they are more than half to three-fourths grown.

From 128 fruits, about three-fourths grown, picked from the ground during April, 1913, 2,929 adults, or an average of about 23 adults per fruit, were reared. From 10 of these fruits 34, 12, 25, 8, 49, 78, 64, 17, 6, and 54 adults, respectively, were reared. As many as 90 larvæ have been taken from a single fruit.

The writers have on file data secured during experimental work on the infestations of several thousand individual fruits, but they throw no additional light on the severity of peach infestation.

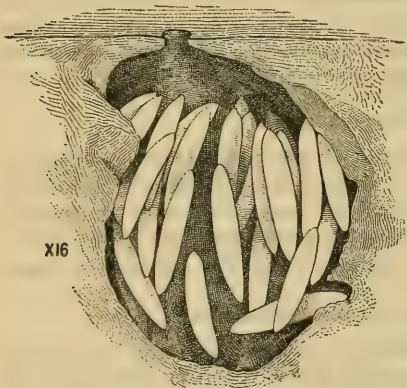


FIG. 3.—Cross section of peach, showing the general shriveling of the walls of the egg cavity and the separation of the eggs. Drawing made 1½ days after oviposition. (Authors' illustration.)

60–62. NECTARINE (*Prunus persica* var. *nectarina*), APRICOT (*Prunus armeniaca*), and PLUM (*Prunus* spp.).

Varieties of *Prunus* spp. known as plums, apricots (fig. 4), and nectarines are reported well infested where grown in infested regions. These fruits are imported in season to Hawaii from California and have been easily infested under forced laboratory conditions. It seems probable that they will serve best as hosts when partially grown, as the excessive moisture content of the well-ripened fruits, particularly of such varieties as the Japanese plums, causes a high mortality among young larvæ.

63. POMEGRANATE (*Punica granatum*).

The writers have never reared *C. capitata* from pomegranate. Mr. O. H. Swezey, of Honolulu, reared an adult identified by the senior writer as *C. capitata* from a fruit partially decayed. The writers have examined many perfect and split fruits without detecting evidences of infestation. Compere records finding infested fruits in Asia Minor, and Trabut in 1901 reports infestation in Algeria.

64. APPLE (*Pyrus* spp.).

Only a few apple trees (*Pyrus malus*) are found growing in those regions of Hawaii sufficiently warm for *C. capitata*, hence the writers can offer no observations on the infestation of this fruit occurring in the field. Apples have been found infested in

South Africa and Australia by other investigators. Gurney, of New South Wales, lists the apple among host fruits occasionally infested. Wickens, in 1914, in western Australia, writes that "the apple growers who have been hoping that they would not suffer so severely as growers of soft fruits are now becoming seriously alarmed at the presence of fruit-fly punctures and larvæ in their export varieties of apples. Fortunately the two apple-producing centers of the State (Bridgetown and Mount Baker) are free from the pest." Lounsbury, in South Africa, writes that "ordinarily only peaches, nectarines, and pears are severely infested, but last year apricots, figs, pears, plums, apples, and quinces were almost all attacked." Newman states that in western Australia eggs deposited in undeveloped apples and pears rarely hatch and that if they do the larvæ die. The senior writer found apples grown throughout eastern and southern Spain quite generally infested during 1916.

The writers have used apples extensively in their experimental work and have found them an excellent fruit for securing large numbers of larvæ and eggs for temperature studies. The firmer apples, if not overinfested, serve better than any fruit as a medium for carrying the pest along within the laboratory for considerable periods. Some fruits become too moist and these are not satisfactory. For one type of infestation see Plate I, figure 2, and Plate XI, figure 2.

65. PEAR (*Pyrus* spp.).

There are few pear trees grown in yards in Honolulu. The fruits are generally and badly infested, the interior often becoming badly eaten out by larvæ while the exterior appears unaffected. Often fruits, entirely destroyed, may dry up and remain attached to the tree. Such a fruit is illustrated in Plate VII, figure 2.

66. SANDALWOOD (*Santalum freycinetianum* var. *littorale*).

Adults of *C. capitata* were reared during the summer of 1916 from the fruits of the native sandalwood by Messrs. O. H. Swezy and J. C. Bridwell. The infested material was taken from a tree growing about 50 feet above sea level at Waianae, Island of Oahu.

67. EGGPLANT (*Solanum melongena*).

The eggplant (*Solanum melongena*) has been found infested only once during four years by the writers. One hundred and fifteen fruits of all ages gathered from the vines in the Moiliili market garden during April 26-30, 1914, showed no infestation when examined May 2 to 5 by the removal of the skin. One thousand fruits in all conditions of soundness were examined by the junior writer during November, 1915, by carefully removing the skin from each fruit. In only one fruit were larvæ found. These were well grown, several in number, and in tunnels immediately beneath the skin. Adults of *C. capitata* were reared from these larvæ. The senior writer has personally examined many fields superficially, but has never seen infestation due to either *C. capitata* or *Bactrocera cucurbitae*.

68. WI (*Spondias dulcis*).

The "wi" (*Spondias dulcis*), a native tree of the Society Islands but common to the tropics of both hemispheres, is common in Honolulu and bears heavily. Its fruits are only slightly infested by *C. capitata*. From 200 very ripe fruits gathered on

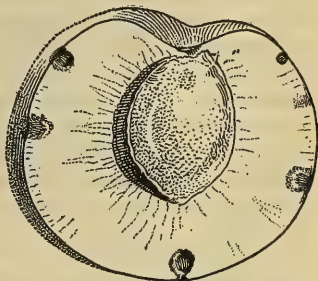


FIG. 4.—Small apricot, natural size, showing eggs of the Mediterranean fruit fly deposited in five places. (Original.)

October 2, 1913, only 7 adults were reared. Four adults were reared from 33 ripe fruits in which many eggs were laid under forced laboratory conditions during December, 1915, and January, 1916. The fruits usually ripen uninfested.

69. NATAL PLUM (*Terminalia chebula*).

The Natal plum (*Terminalia chebula*) is well infested as the fruits ripen and has proved an excellent source of larvæ for experimental work. From two lots of fruit of 12 pounds each, 2,761 and 2,655 adults, respectively, were reared during October-November, 1915.

70. TROPICAL ALMOND OR WINGED KAMANI (*Terminalia catappa*).

The tropical almond or winged kamani (*Terminalia catappa*) is a preferred host. It is one of the most reliable sources for fruit-fly material in the Hawaiian Islands. The pulp, upon which the larvæ feed as the fruit ripens, is scarcely three-eighths of an inch thick. (See Pl. XIX.) Severin obtained from 25 fruits 1,380 larvæ; 98 larvæ from one fruit. The writers have reared many thousands of larvæ for experimental work. From 16 lots of fruit from different Honolulu localities collected during October, 1915, totaling 1,531 fruits, 10,005 larvæ developed. From 3,902 fruits collected from 28 localities during November and December, 1915, only 11,481 larvæ developed. It remains to be seen whether the scarcity of larvæ in the fruits developing during late 1915 was due to the work of parasites or to other causes.

71. BESTILL (*Thevetia neriiifolia*).

The bestill or yellow oleander (*Thevetia neriiifolia*) is never infested until it begins to turn black when ripening. Until then it is excellently protected by its white sticky sap which exudes rapidly from any slight abrasions in the epidermis. The pulp is quite dry and pithy and often escapes infestation, particularly during dry spells. When the fruits ripen very slowly during colder weather and fall to damp shaded spots, as many as 38 adults may be reared from a single fruit. In Bermuda, in the absence of an abundance of other hosts, the *Thevetia* was found very badly infested with unusually large larvæ during December. In Honolulu many fruits ripen uninfested.

72. GRAPE (*Vitis labrusca*).

The Isabella grape (*Vitis labrusca*) is the only grape grown in any quantity in Hawaii. The fruits mature and are sold on the markets and appear to be entirely free from fruit-fly attack. This variety of grape is, however, subject to slight attack. One fruit inspector detailed to collect suspicious-appearing fruits brought to the office 978 berries as the result of a 4-day search. A careful examination by H. F. Willard of these with a hand lens revealed five well-grown larvæ in two lots of fruit totaling 201 berries. Two of the larvæ died, but the other three developed into adults identified as *C. capitata*.

Newman, in western Australia, states, in 1912, that he found *C. capitata* frequently in grapes, yet in 1914 he writes that at Crawley little or no sound fruit had been picked for years except grapes. Lounsbury, in 1907, states that he found grapes only slightly infested in South Africa. Whatever the degree of infestation is elsewhere, in the Hawaiian Islands it is so slight that it is never noticed in the vineyards where fruit is grown for the production of wine or where fruits are ripening for table purposes on isolated vines growing in badly infested districts of Honolulu. Excellent bunches of grapes are picked within a few feet of badly infested peaches.



A HOST FRUIT OF THE MEDITERRANEAN FRUIT FLY.

FIG. 1.—A large winged kamani tree (*Terminalia catappa*) with a 6-foot man standing beneath for comparison. The fruits of this species are badly infested and, because they ripen and fall in large or small numbers during the entire year, greatly interfere with successful clean-culture work. FIG. 2.—The nuts are from 2 to 2.5 inches long; the fruit-fly larvæ feed only on the thin pulp covering the nut. (Original.)

LIFE HISTORY AND DESCRIPTION.

THE EGG.

DESCRIPTION.

The eggs (figs. 3-6) are glistening white, about 0.945 mm. long, elongate elliptical, and often more convex on the dorsal side.

DURATION OF EGG STAGE.

Martelli gives the duration of the egg stages at Portici, Italy, as 2 days in August and from 4 to 5 days in October. Newman states that in Western Australia eggs hatch in from 2 to 4 days during summer and in from 14 to 19 days during winter. Mally, in South Africa, found the egg stage to be from 2 to 4 days in midsummer. Other data have been published but give no additional information and, being unaccompanied by temperature records, may be omitted. Newman appears to be the only investigator who has made an effort to secure data for the winter period.

In Honolulu, or littoral Hawaii in general, the length of the egg stage is very short, and agrees with the minimum periods indicated by writers in other countries. In Table XII are recorded data on observations on 4,066 eggs secured at Honolulu, which indicate that the largest number of eggs hatch in from 2 to 3 days after deposition during the hottest weather. At a mean temperature of 79° F., 208

eggs hatched in from 49 to 51 hours after deposition, while 79 hatched in from 52 to 53

hours, and 3 in from 53 to 54 hours. At a mean temperature of 78.9° F., 134 eggs hatched between 49 and 54

hours after deposition, although 12 eggs deposited at the same time did not hatch until from 66 to 72 hours later. At a mean of 71° F., 695 eggs hatched within 72 hours, while 3 hatched in from 120 to 144 hours, or about 6 days after deposition. At a mean of 70.5° F., 437 eggs hatched in from 77 to 83 hours after deposition and 227 after a period of 83 to 91 hours had elapsed. At a mean of 69.8° F.,

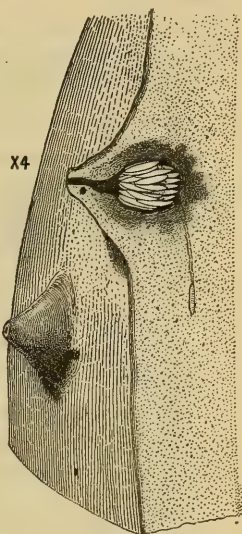


FIG. 5.—Section of grapefruit rind, showing two egg cavities, one in cross section. Drawing made one week after fruit was picked. Note conical elevation about the egg cavities left by the withering of the rind; also the thickened walls of the egg cavity and the single larval channel in the rag. (Authors' illustration.)

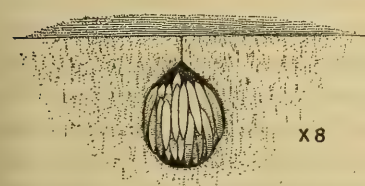


FIG. 6.—Cross section of peach, showing egg cavity of the Mediterranean fruit fly with eggs. Drawing made directly after oviposition. (Authors' illustration.)

356 eggs hatched after a period of from 84 to 91 hours, 216 after 91 to 92 hours, 127 after 92 to 93 hours, 33 after 93 to 94 hours, 8 after 94 to 95 hours, 5 after 95 to 96 hours, and 3 after 104 to 106 hours. Eighty-eight eggs hatched between 4 and 4.5 days after deposition at a mean temperature of 68.7° F.

TABLE XII.—*Duration of the egg stage of the Mediterranean fruit fly at Honolulu under normal conditions.*

Number of eggs under observation.	Eggs deposited.	Eggs hatched.	Average mean temperature.
			° F.
88	Jan. 21-22, 4 p. m. to 10 a. m.	Jan. 26, 6 a. m. to 3 p. m.	68.7
350	Mar. 9, 10 a. m. to 12 m.	Mar. 12-13, 4.30 p. m. to 8 a. m.	70.2
102	Mar. 27, a. m. to 1 p. m.	Mar. 30, a. m.	71
695	do.....	Mar. 30, a. m., to Mar. 31, a. m.	71
28	do.....	Mar. 31-Apr. 1, 9 a. m. to 8 a. m.	71
3	do.....	Apr. 1, 2 p. m. to 8 a. m.	71
176	May 12-13, 3 p. m. to 12 m.	May 15, a. m.	75
243	do.....	May 15-16, 2 p. m. to 8 a. m.	75
44	June 18, 1.30 to 3.30 p. m.	June 20-21, 6 p. m. to 8 a. m.	77
90	June 19, 10 a. m. to 1 p. m.	June 21-22, 6 p. m. to 8 a. m.	76.6
77	June 20, 9 a. m. to 4 p. m.	June 22-23, 6 p. m. to 7.30 a. m.	77
63	June 24, 1.30 to 4.30 p. m.	June 26-27, 4.30 p. m. to 6 a. m.	77
134	July 15, 3.30 to 4.30 p. m.	July 17, 4.30 to 6 p. m.	78.9
128	do.....	July 17, 6 to 8 p. m.	78.9
20	do.....	July 17, 9 to 10 p. m.	78.9
12	do.....	July 18, 10 a. m. to 4 p. m.	78.3
208	Aug. 24, 10.30 to 11.30 a. m.	Aug. 26, 11.30 a. m. to 1 p. m.	79
79	do.....	Aug. 26, 1 to 2 p. m.	79
3	do.....	Aug. 26, 2 to 3 p. m.	79
47	Sept. 9, 3 to 4 p. m.	Sept. 11, 3 to 9 p. m.	79.7
101	Nov. 13-14, 4 p. m. to 9 a. m.	Nov. 16, 2 to 6 a. m.	75.5
10	do.....	Nov. 16, 6 to 11 a. m.	75.5
356	Dec. 15, 11 a. m. to 1 p. m.	Dec. 18-19, 11 p. m. to 6 a. m.	69.8
216	do.....	Dec. 19, 6 to 7 a. m.	69.8
127	do.....	Dec. 19, 7 to 8 a. m.	69.8
33	do.....	Dec. 19, 8 to 9 a. m.	69.8
8	do.....	Dec. 19, 10 to 11 a. m.	69.8
5	do.....	Dec. 19, 11 a. m. to 12 m.	69.8
3	do.....	Dec. 19, 8 to 10 p. m.	69.8
437	Dec. 16, 11 a. m. to 1 p. m.	Dec. 19, 4 to 10 p. m.	76.5
227	do.....	Dec. 19-20, 10 p. m. to 6 a. m.	70
4,066			

While eggs hatch in from 2 to 6 days after deposition in any fruit-growing section in the Hawaiian Islands, they may require a much longer period for development under colder weather conditions. In the course of experimental work, the writers have secured data showing that under varying conditions of temperature the duration of the egg stage may be extended to at least 25 days. In Table XIII data of special interest, as indicating how dependent embryonic development is upon temperature, are recorded.

All of 131 eggs one day old when placed at Puulehua, where the temperature ranged between 39° and 89° F., with a mean of about 52° F., were still unhatched after 16 days at Puulehua, after which they were taken to Kealakekua, where they hatched the following day, or when 18 days old.

Twenty-three eggs deposited in apples at Kealakekua, Kona, Hawaii, at about 1,100 feet elevation, on February 9-10, 1915, and taken on February 11 to the summit of Hualalai, 8,250 feet eleva-

tion, where the temperature ranged between 30° and 62° F., with a mean of 46° F. for the period of observation, were still unhatched after exposure for 14 days. After 14 days on Hualalai eggs were carried in their host to Kealakekua and there hatched on February 27, or 17 to 18 days after they were deposited.

Additional information on the duration of the egg stage has been secured under cold-storage conditions. Eggs hatch in refrigeration at temperatures ranging between 54° and 62° F. Five eggs deposited August 15-16 and placed in a refrigerator at 54° to 57° F. on August 16 hatched within the refrigerator on August 23, or in from 7 to 8 days after deposition; 19 eggs deposited at the same time were removed unhatched on August 23 but hatched on the 24th, outside the refrigerator, or 8 or 9 days after deposition. A single egg also deposited on August 15-16 and similarly placed at 54° to 57° F. had not hatched by August 30, when it was removed to normal temperature, where it hatched within 24 hours, or 14 or 15 days after deposition. Thirty-two eggs deposited on July 15-16 and placed on July 16 at 58° to 62° F. hatched in the refrigerator on July 20 or in from 4 to 5 days after being deposited, whereas 6 eggs of the same lot were unhatched in storage on July 24, after which they were removed to normal temperatures where they hatched on July 25, or 7 to 8 days after deposition. Eggs deposited on February 11-12, and placed at 48° to 52° F. on February 12, failed to hatch at this temperature, but 20 removed after 14 days hatched within 16 to 17 days after deposition; 11 removed after 19 days hatched within 21 to 22 days after deposition; while 1 removed after 22 days of refrigeration hatched on March 8, or 24 to 25 days after deposition. The examination of a second lot of fruit containing 1,853 eggs, deposited during a 24-hour period before they were placed at a temperature of 48° to 53° F., showed that one egg hatched in storage 18 days after the inward date and after 24 and 27 days of refrigeration 64 and 56 first-instar larvæ had hatched and died in the punctures. Of these 1,853 eggs, 1,014 removed after refrigeration for 18 to 27 days were dead; of 115 removed to normal temperatures after refrigeration for 16 days, 35, 25, and 9 hatched in 17, 18, and 19 days, respectively, after deposition. Eggs deposited during a 4-hour period were placed immediately at 49° to 56° F.; after refrigeration for 21 days, 1 living and 7 recently dead first-instar larvæ and 51 unhatched eggs were found. Of other eggs deposited at the same time but held at normal temperatures for from 44 to 47 hours before being placed in storage, 8, 12, and 48 had hatched after refrigeration for 16, 19, and 21 days. One egg, two days after deposition, was held in storage at a temperature of from 40° to 45° F. for 20 days (June 27 to July 17), when it was removed to normal temperatures where it hatched three days later, or 25 days after deposition. One egg

placed in storage at 26° to 30° F. when one day old, and held at this temperature for 7 days, hatched three days after removal, or 11 days after deposition.

TABLE XIII.—Duration of the egg stage of the Mediterranean fruit fly under low temperature conditions.

Number of eggs under observation.	Eggs deposited.	Cold-storage dates.		Dates of hatching.	Number of days in storage.	Length of egg stage.	Temperatures.	
		Inward.	Outward.				Range in storage.	Mean outside storage.
							° F.	° F.
10	July 6, 1913.....	July 7	July 8	July 9	1	3	26-30	78
4	do.....	do.....	July 9	July 10	2	4	26-30	78
1	do.....	do.....	do.....	July 12	2	6	26-30	78
2	do.....	do.....	July 8	do.....	1	6	26-30	78
388	Nov. 3, 1914.....	Nov. 4	Nov. 8	Nov. 10	4	7	26-30	76.5
6	June 30, 1913.....	July 2	July 8	July 9	6	9	26-30	77
1	Nov. 3, 1914.....	Nov. 4	Nov. 11	Nov. 14	7	11	26-30	76.5
520	Sept. 25, 1914.....	Sept. 26	Sept. 28	Sept. 29	2	4	32	77.6
216	do.....	do.....	Sept. 30	Oct. 2	4	7	32	77.6
1	do.....	do.....	Oct. 5	Oct. 7	9	12	32	77.5
21	Sept. 7, 1914.....	Sept. 9	Sept. 17	Sept. 19	8	12	33-34	79.5
4	do.....	do.....	do.....	Sept. 21	8	14	33-34	78.9
242	Nov. 16, 1914.....	Nov. 17	Nov. 25	Nov. 28	8	12	36	69.5
5	do.....	do.....	Nov. 27	Dec. 1	10	15	36	70.4
5	July 4, 1913.....	July 5	July 8	July 9	3	5	33-38	77.2
11	do.....	do.....	July 9	July 12	4	8	33-38	77.4
13	do.....	do.....	July 16	July 18	11	14	33-38	78.2
1	July 17, 1913.....	July 18	Aug. 1	Aug. 4	14	18	33-38	78.9
1	June 25, 1913.....	June 27	Aug. 18	Aug. 30	3	5	38-45	77.8
3	do.....	do.....	do.....	July 2	3	7	38-45	77.6
7	do.....	do.....	do.....	July 5	8	11	38-45	77.3
1	do.....	do.....	July 8	July 10	11	15	38-45	77.4
6	do.....	do.....	July 14	July 15	17	20	38-45	77.7
1	do.....	do.....	July 17	July 18	20	23	38-45	77.9
1	do.....	do.....	do.....	July 20	20	25	38-45	77.8
20	Feb. 11-12, 1915....	Feb. 12	Feb. 26	Feb. 28	14	16-17	48-53	69.8
11	do.....	do.....	Mar. 3	Mar. 15	19	21-22	48-53	70.5
1	do.....	do.....	Mar. 6	Mar. 8	22	24-25	48-53	70.6
19	Aug. 15-16, 1914....	Aug. 16	Aug. 23	Aug. 24	7	8-9	54-57	79.1
5	do.....	do.....	(¹)	Aug. 23	7	7-8	54-57	79.1
1	do.....	do.....	Aug. 30	Aug. 31	14	14-15	54-57	79.1
32	July 15-16, 1914....	July 16	(¹)	July 20	4	4-5	59-62	79.5
6	do.....	do.....	July 23	July 24	7	7-8	59-62	79.5
172	Sept. 9, 11 a. m. to 2 p. m.	Sept. 9, 3 p. m.	(¹)	Sept. 16	7	7	60-64	79.2
23	Feb. 9-10, 1915.....	² Feb. 11	Feb. 25	Feb. 27	.....	17-18	³ 30-62	69.4
131	Feb. 20, 1915.....	³ Feb. 21	.....	Mar. 6	.....	14	⁴ 39-89	67.8
1,720								

¹ Fruit not removed. Eggs hatched in storage.

² Not placed in cold storage, but exposed to normal temperatures at summit of Mount Hualalai, 8,200 feet elevation.

³ Not placed in cold storage, but exposed to normal temperature at Puulehua, about 4,500 feet elevation.

⁴ Mean temperature about 46° F.

⁵ Mean temperature about 70° F.

These data, together with those recorded in Table XIII, demonstrate the great variation, from a fruit-fly standpoint, in the duration of the egg stage.

THE LARVA.

DESCRIPTION.

A clear idea of the general shape of the larva or maggot of the Mediterranean fruit fly can be gained by reference to text figures 7 and 8, and Plate XIII, figure 1. When first hatched from the egg, the larva is about 1 mm. long but increases in size to from 7-8 mm. long when full grown. Each larva passes through three well-defined

instars. While normally white in color, it may appear creamy yellow, pink, or with colorations of red or black, according to the nature of its food, which shows through the semitransparent body walls.

First larval instar (fig. 8).—Length about 1 mm. The first-instar larva is so small that it is seldom observed. Aside from its size, it is most easily distinguished from the succeeding instars by the absence of anterior spiracles. The tracheal system in this instar opens to the exterior only at the posterior spiracles, and consists of two main

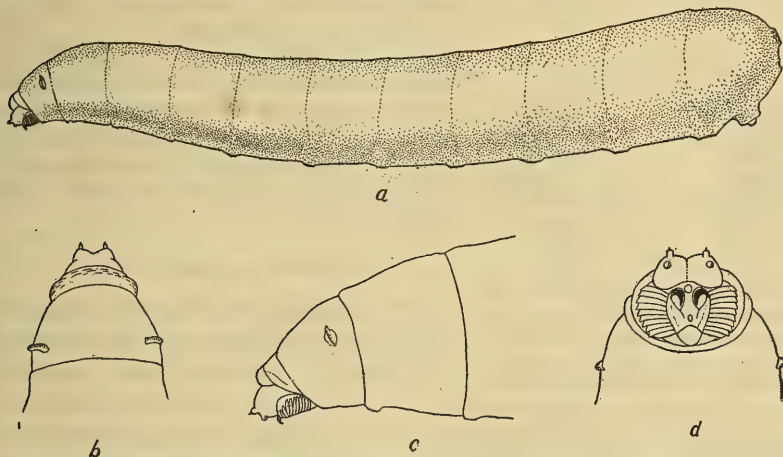


FIG. 7.—Third-instar larva of the Mediterranean fruit fly: *a*, Lateral view of entire larva; *b*, dorsal view of anterior portion; *c*, lateral view of same; *d*, ventral view. (Original.)

trunks extending the full length of the body. The posterior stigmatic plates, the outer edges of which are about 0.061 mm. apart, have two instead of three slits, as illustrated in figure 9, *a*. The mandibles or mouth hooks are not conspicuous and are of the shape indicated in figure 10, *a*.

Second larval instar.—In size the second larval instar is sufficiently large to be distinct from the first instar, but not from undersized third-instar larvæ. It may, however, be easily distinguished from the third instar by the shape of the anterior spiracles

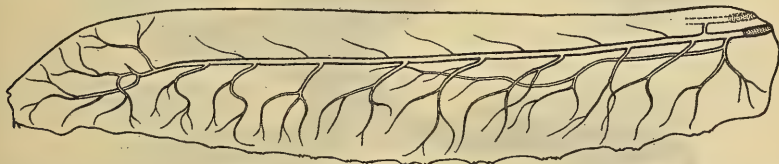


FIG. 8.—First-instar larva of the Mediterranean fruit fly, showing one of the two main tracheal systems opening at the posterior spiracles. (Original.)

(fig. 11, *a*), the mandibles (fig. 10, *b*), and posterior spiracles (fig. 9, *b*). The distance between the outer edges of the stigmal plates is about 0.13 mm.

Third larval instar.—The third-instar larva, which is about 7 to 8 mm. long, may be distinguished when well grown from the two preceding instars by its jumping habit when removed from its host, by the well-defined mandibles or mouth hooks (fig. 10, *c*), and by the prominence of the posterior spiracles. The anterior spiracles possess from 9 to 10 lobes (fig. 11, *b*) and are borne on the second segment as in the preceding stage. The posterior stigmal plates each bear three slits arranged as illustrated and are armed with four batches of delicate inconspicuous hairs (fig. 12).

The dotted lines of figure 12, indicate the general shape of the terminal chambers of the tracheal system. The body is composed of 12 distinct segments, the last of which bears the posterior stigmata upon the upper distal portion and the anus before the center of the venter in the middle of a rounded tubercle (fig. 7, a). The head when viewed

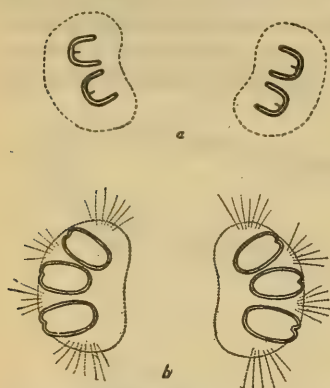


FIG. 9.—Posterior spiracles of larvæ of the Mediterranean fruit fly: a, First-instar larvæ; b, second-instar larvæ. (Original.)

from above or below is bilobed; each lobe bearing a distinct antennal protuberance; the dorsal and more distal one terminating in a short inconspicuous arista; the more ventral one less antennalike and without a terminal arista (fig. 7, b, c, d). Mouth hooks sheathed (fig. 7, d). Body armed only with inconspicuous spicules arranged in broken bands forming fusiform areas on the venter of the 4–12 segments; portions of the head and an irregular ring upon the anterior portion of segments 2 and 3 armed with similar spicules. There are no distinct fusiform lateral areas of spicules.

DURATION OF LARVA STAGE.

The duration of the larval instars has been variously given by many writers.

Martelli found that larval development at Portici, Italy, required from 9 to 10 days during summer, 11 to 12 days during early autumn, and 15 days during November and December. Severin found that larvæ matured in the winged kamani (*Terminalia catappa*) in from 8 to 17 days. Newman states that from 14 to 16 days during summer and 25 to 45 days during winter in Western Australia are the periods required for development. Other data might be given but they add

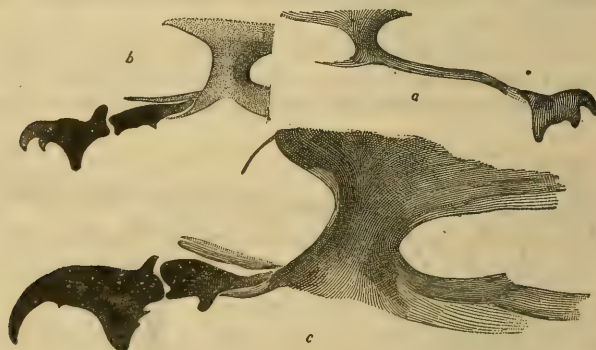


FIG. 10.—Mandibles of larva of the Mediterranean fruit fly: a, First-instar larva; b, second-instar larva; c, third-instar larva. (Original.)

nothing new to the foregoing information. No records previously published except by the writers have been accompanied by temperature data, hence they can not be satisfactorily interpreted.

In Honolulu larval life¹ is completed within 5.1 to 26 days. The data in Table XIV indicate the variation found in the developmental

¹ Back, E. A., and Pemberton, C. E. Life history of the Mediterranean fruit fly from the standpoint of parasite introduction. Jour. Agr. Research, v. 3, no. 5, 1915, p. 363-374.

period. During June when the mean temperature was 77.6° F. two larvæ completed their entire development in 5.1 and 5.5 days, respectively, but they were transferred daily to fresh pieces of ripe papaya and thus were surrounded by the best of conditions. However, other larvæ equally well cared for and similarly fed and transferred did not reach maturity and pupate until 6.7, 12, and 14 days. Ordinarily larvæ complete their development in from 6 to 10 days at an average mean temperature of 76° to 79° F.

During the cooler part of the year, when the average mean temperature is about 69.6° F., larvæ transferred daily to fresh ripe papaya did not become fully grown until 9, 10, and 14 days old, while at about the same temperature 18, 12, and 1 larvæ required 10, 11, and 15 days for development in a green half-grown peach. At a mean temperature of about 70° to 71° F., 12, 14, 3, 1, and 1 larvæ pupated 14, 16, 19, 22, and 26 days, respectively, after hatching. Larvæ hatching during December 25 to

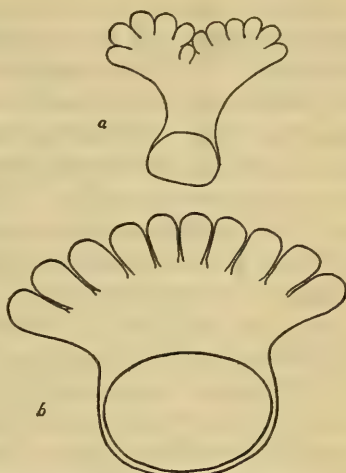


FIG. 11.—Anterior spiracles of larva of the Mediterranean fruit fly: *a*, Second-instar larva; *b*, third-instar larva. (Original.)

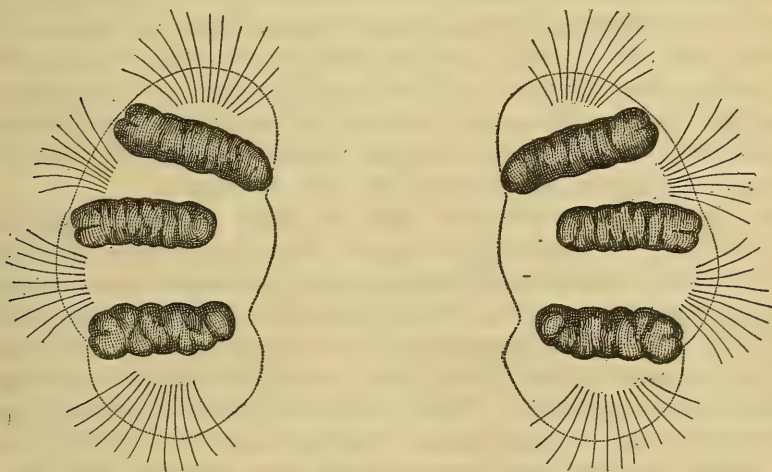


FIG. 12.—Posterior spiracles of third-instar larva of the Mediterranean fruit fly. (Original.)

26 in a very firm textured apple required 19, 25, and 35 days for development when the mean temperature averaged about 68° F. Four and 3 larvæ became full grown in 6 and 7 days, respectively, in a ripe soft peach at a mean temperature of from 77° to 78° F., whereas

under identical conditions 6 larvæ required 9.5 days in a ripe but still hard peach.

All data secured by the writers indicate that during the warmest portions of the year larval development progresses rapidly and fairly uniformly. With the approach of colder weather larval life is not only lengthened but subject to considerable and entirely unexplainable variation, even with larvæ hatching at the same time in the same fruit, especially if the host fruit happens not to be in the best condition to support larval life. The three larvæ requiring 19, 25, and 35 days for development in a very hard apple furnish a good example. In Table XV are recorded data showing the ability of cold weather greatly to increase larval life.

The data in Table XIV indicate that under favorable conditions as regards temperature and host the first larval instar is passed in from 26 to 48 hours, the second in 24 to 48 hours, and the third in 48 to 265 hours. It is profitable, therefore, to compare these and other data in Table XIV with the data of Table XV.

At an elevation of 8,250 feet, on the summit of Mauna Hualalai, Hawaii, where the temperature ranged between 27° and 73° F., but averaged for the period about 48° F., the first larval instar was found to range up to 57 days. Eighty-nine larvæ in apples were found still in the first instar after 30 days, 3 after 46 days, 7 after 54 days, and 1 after exposure for 57 days. Thirty-three larvæ in the second instar placed on Hualalai were still in this instar after 32 days, and 1 after 54 days. At Strawberry, Hawaii, a ranch station, where the temperature ranged from 39° to 79° F., 49 first-instar larvæ were found still in this instar after 27 days and 19 after 29 days. At Kealahakua, where the temperature ranged between 58° and 80° F., with a mean of about 68° F., three larvæ in apples required 28, 58, and 74 days to become fully grown and to leave the fruit to pupate.

In cold storage under what may be called artificial conditions, larval life may be variously prolonged. Thus one second-instar larva and one third-instar larva in peaches placed in storage at temperatures varying from 40° to 45° F. were found still in those instars at the end of 29 and 45 days, respectively, while check larvæ at the laboratory in the same species of host fruit completed their entire development in from 6 to 9 days. Three third-instar larvæ in apples placed in a refrigerator at temperatures varying from 48° to 52° F. were still active after 60 days and one was alive after 79 days. In a second refrigerator at temperatures ranging from 58° to 62° F., larvæ completed their development and pupated in 24, 36, 40, 44, and 50 days.

TABLE XIV.—*Duration of the larva stage of the Mediterranean fruit fly in Honolulu.*

Host fruit.	Number of specimens under observation.	Larva hatched.	Molted into second stage.	Molted into third stage.	Larva pupated.	Length of larva stage.	Temperature of developmental stage.	
							Range.	Mean.
Papaya.....	3	Dec. 19, 9 to 10 a. m.	Dec. 21, 10 a. m. to 2 p. m.	Dec. 23, 4 p. m.	Dec. 28, 12 m.	9	° F. 61-78	° F. 69.6
Do.....	1	do.....	do.....	Dec. 23, 10 a. m. to 2 p. m.	Dec. 28, 4 a. m.	9	61-78	69.6
Do.....	2	do.....	do.....	Dec. 23, 4 to 10 p. m.	do.....	9	61-78	69.6
Do.....	1	do.....	do.....	Dec. 23, 10 a. m. to 2 p. m.	Dec. 28, 12 m.	9	61-78	69.6
Do.....	1	do.....	do.....	Dec. 23, 4 to 10 p. m.	Dec. 28, 10 a. m.	9	61-78	69.6
Do.....	1	do.....	do.....	Dec. 23, 2.45 p. m.	Dec. 28, 11 a. m.	9	61-78	69.6
Do.....	1	do.....	do.....	Dec. 23, 4 to 10 p. m.	do.....	9	61-78	69.6
Do.....	1	do.....	do.....	do.....	Dec. 28, 12 m.	9	61-78	69.6
Do.....	1	do.....	do.....	do.....	Dec. 29, 4 a. m.	10	61-78	69.6
Do.....	1	do.....	Dec. 21, 2 to 4 p. m.	Dec. 23-24, 10 p. m. to 6 a. m.	Dec. 29, 3 p. m.	10	61-78	69.6
Do.....	1	do.....	Dec. 21, 4 to 9 p. m.	do.....	Dec. 29, 12 m.	10	61-78	69.6
Do.....	1	do.....	Dec. 21, 10 a. m. to 2 p. m.	do.....	Jan. 2, 1 p. m.	14	61-79	70
Do.....	2	June 12, a. m.	June 14, a. m.	June 16, a. m.	June 18, a. m.	5.1	71-83	77.6
Do.....	3	June 12, p. m.	do.....	do.....	do.....	5.5	71-83	77.6
Do.....	1	June 19, a. m.	June 20-21, 4 p. m. to 8 a. m.	June 21-22, 4 p. m. to 8 a. m.	July 1, a. m.	12	72-83	77
Do.....	1	do.....	do.....	do.....	July 3, a. m.	14	72-83	77.1
Do.....	1	do.....	June 20, 1 to 4 p. m.	do.....	June 25, p. m.	6	72-83	76.4
Do.....	17	do.....	June 20-26, 4 p. m. to 8 a. m.	do.....	do.....	6	72-83	76.4
Do.....	2	do.....	do.....	do.....	June 26, a. m.	7	72-83	76.6
Green peach	2	June 22.....	do.....	do.....	July 2.....	10	72-83	77.2
Do.....	7	do.....	do.....	do.....	July 3.....	11	72-83	77.2
Ripe hard peach.	6	June 26.....	do.....	do.....	July 6.....	9.5	72-83	77.4
Ripe soft peach.	4	do.....	do.....	do.....	July 2.....	6	72-83	77.8
Do.....	3	do.....	do.....	do.....	July 3.....	7	72-83	77.7
Green peach	18	Mar. 31.....	do.....	do.....	Apr. 10.....	10	61-77	69.6
Do.....	12	do.....	do.....	do.....	Apr. 11.....	11	61-77	69.8
Do.....	1	do.....	do.....	do.....	Apr. 15.....	15	61-82	71.0
Commercial lemon.	12	Mar. 13.....	do.....	do.....	Mar. 27.....	14	57-80	70.2
Do.....	14	do.....	do.....	do.....	Mar. 29.....	16	57-80	70.3
Do.....	3	do.....	do.....	do.....	Apr. 1.....	19	57-80	70.5
Do.....	1	do.....	do.....	do.....	Apr. 4.....	22	57-80	70.4
Do.....	1	do.....	do.....	do.....	Apr. 8.....	26	57-80	70.4
Apple.....	1	Dec. 25, 1914..	do.....	do.....	Jan. 13, 1915..	19	67-81	71.6
Do.....	1	do.....	do.....	do.....	Jan. 19, 1915..	25	67-81	71.1
Do.....	1	Dec. 26, 1914..	do.....	do.....	Jan. 30, 1915..	35	67-81	70

The data recorded in Table XV only indicate the possibilities in lengthening larval life. Except at temperatures from 58° to 62° F., none of the larvæ would have been able to mature had they been kept at the temperatures recorded. The data merely bring out the fact that upon the examination of the host fruits after so many days the larvæ recorded were found alive. A very large percentage of the larvæ within the same fruits were dead, but this mortality, due to exposure to cold for prolonged periods, is discussed elsewhere.

TABLE XV.—Showing ability of low temperatures to lengthen larval life of the *Mediterranean fruit fly*.¹

Number of specimens under observation.	Instar.	Locality.	Temperature:		Length of instar of instars.
			Range.	Mean.	
			°F.	°F.	Days.
1	2	Cold storage.....	33-38	.....	15
2	3		33-38	.....	17
1	2		40-45	.....	29
1	3		40-45	.....	45
12	3	Refrigerator No. 1.....	48-54	50	24
1	3		48-54	50	36
3	3		48-54	50	60
1	3		48-54	50	79
1	1, 2, 3	Refrigerator No. 3.....	58-62	60	24
1	1, 2, 3		58-62	60	36
1	1, 2, 3		58-62	60	40
1	1, 2, 3		58-62	60	44
3	1, 2, 3	Kealakekua.....	58-62	60	50
1	1, 2, 3		58-80	69	28
1	1, 2, 3		58-80	69	58
1	1, 2, 3		58-80	69	74
41	1	Hualalai.....	27-73	48	12
1	1		27-73	48	26
89	1		27-73	48	30
1	1		27-73	48	45
3	1	Hualalai.....	27-73	48	46
7	1		27-73	48	54
1	1		27-73	48	57
33	2		27-73	48	32
1	2	Puulehua.....	27-73	48	54
133	1		.....	.....	54
1	1		.....	.....	17
14	1		.....	.....	36
49	1	Strawberry.....	39-79	.....	27
19	1		39-79	.....	29

¹ In securing these data apples were used as host fruits in all but the first four records for cold storage, for which peaches were used.

In spite of the ability of cold temperatures to prolong larval life greatly beyond the usual period required for development during warm Hawaiian weather, it is interesting to record that individual larvæ whose development has been slowed down, or even practically suspended, will continue their development normally when returned to warmer temperatures. Thus one second-instar larva which had been held for 54 days on Hualalai on being taken to Kealakekua on March 26, where the mean temperature was about 66.8° F., and then to Honolulu on March 29, molted into the third instar on March 30. A second larva placed on Hualalai just after hatching and kept there until March 17, or 45 days, on being taken to Kealakekua molted into the second instar on March 21, into the third instar on March 24, pupated March 28, was taken to Honolulu on March 29, and emerged as an adult on April 10.

PUPA.

DESCRIPTION OF PUPARIUM.

Puparium (Fig. 13, a, b, c).—Puparium elliptical in general shape; a little more convex on the dorsal side; length about 4 to 4.5 mm. The size and color of puparium vary and depend upon the amount and nature of larval food. Puparia formed by larvæ feeding on coffee cherries dull white; the usual color light or dark testaceous. There are only 11 distinct segments, the first being composed of the first and second larval

segments, and therefore bearing indications of the mouth opening and anterior spiracles of latter; last segment likewise bearing the remains of anal and stigmal openings of larva

DURATION OF PUPA STAGE.

Mally has found in South Africa, at Grahamstown, that the duration of the pupa stage may be as long as 35 days in a rearing box kept "at the ordinary seasonal temperature." Martelli states that in southern Italy the pupa stage varies with the progress of the season; that it may be from 10 to 11 days during summer (August), 18 to 20 days during autumn (October), or 30 or more days during the winter. Newman found in Western Australia the periods to be from 12 to 14 days during summer and 25 to 50 days during winter. Nearly all writers have offered data on the duration of this stage, but, un-

accompanied by temperature or humidity records as they are, they add nothing new to the foregoing information.

In a previous paper the writers give data, accompanied by temperature records, on observations including about 2,000 pupæ developing under Honolulu conditions. From these it would appear that the minimum length of pupal life is about 6 days when the mean temperatures range between about 76° and 79° F. During the warmest Honolulu weather the largest proportion of any lot of pupæ require

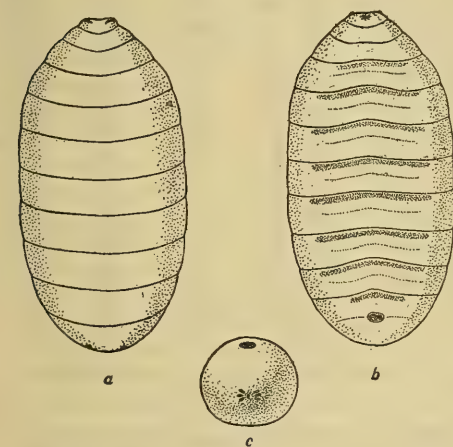


FIG. 13.—Pupa of the Mediterranean fruit fly: *a*, Dorsal view; *b*, ventral view; *c*, posterior end, showing anal scar and spiracles. (Original.)

from 9 to 11 days before yielding adults. Thus at a mean of about 76° F. 5, 14, 101, 160, 7, and 3 pupæ yielded adults 6, 9, 10, 11, 12, and 13 days, respectively, after the formation of the puparium.

The pupa stage may be increased to at least 19 days when the daily means drop to about 69° to 71° F. The data in Table XVI covering observations on 7,000 pupæ are given in corroboration of this statement. At a mean temperature of about 66.8° F., pupæ required from 20 to 28 days to complete their development at Kealakekua, Kona, Hawaii. In Table XVI are given a large number of records covering the coldest portions of the year in the usual fruit-growing sections of the islands. These records, together with many others on file, given in Table XXV in connection with parasite work, indicate that there occurs no dormancy among pupæ at these temperatures. In other words, while development is considerably retarded, there is no yielding of adults by a few pupæ while others

yield adults after a period of dormancy for several months as has been found to be true of the parasites *Diachasma tryoni* and *Diachasma fullawayi*.

TABLE XVI.—Duration of the pupa stage of the Mediterranean fruit fly in Hawaii (7,000 pupæ).

Date of pupation.	Date of emergence.	Number adults emerging.	Length pupa stage.	Mean temperature.	Date of pupation.	Date of emergence.	Number adults emerging.	Length pupa stage.	Mean temperature.
			Days.	° F.				Days.	° F.
Feb. 3 ¹	Feb. 23	9	20	66.8	Dec. 13-20	Jan. 1	167	12-14	72.9
Do.....	Feb. 24	3	21	66.8	Do.....	Jan. 2	466	13-15	72.8
Do.....	Feb. 25	82	22	66.8	Do.....	Jan. 3	152	14-16	72.7
Do.....	Feb. 26	69	23	66.8	Do.....	Jan. 4	3	15-17	72.5
Do.....	Feb. 27	1	24	66.8	Do.....	Jan. 5	2	16-18	72.4
Do.....	Mar. 3	1	28	66.8	Do.....	Jan. 6	1	17-19	72.3
Feb. 27 ²	Mar. 13	7	14	70.4	Dec. 22-29	Jan. 4	27	11-13	72.4
Do.....	Mar. 14	40	15	70.3	Do.....	Jan. 5	528	12-14	72.3
Do.....	Mar. 15	15	16	70.4	Do.....	Jan. 6	541	13-15	72.1
Do.....	Mar. 17	17	18	70.9	Do.....	Jan. 7	804	14-15	71.9
Do.....	Mar. 18	3	19	70.9	Do.....	Jan. 8	57	15-17	71.5
Dec. 1	Dec. 12	8	11	73.2	Do.....	Jan. 10	1	17-19	71.3
Do.....	Dec. 13	279	12	73.1	June 10	June 16	5	6	76.4
Do.....	Dec. 14	269	13	73.1	Do.....	June 19	14	9	76.3
Do.....	Dec. 15	116	14	73.2	Do.....	June 20	101	10	76.3
Do.....	Dec. 16	29	15	73.4	Do.....	June 21	160	11	76.2
Dec. 8-10	Dec. 19	2	9-11	73	Do.....	June 22	7	12	76.1
Do.....	Dec. 20	1	10-12	73	Do.....	June 23	3	13	76.3
Do.....	Dec. 21	98	11-13	73.1	July 13	July 20	1	7	79.2
Do.....	Dec. 22	478	12-14	73.2	Do.....	July 21	3	8	79.2
Do.....	Dec. 23	189	13-15	73.2	Do.....	July 22	39	9	79.2
Do.....	Dec. 24	2	14-16	73.2	Do.....	July 23	43	10	79.1
Dec. 16-18	Dec. 27	24	9-11	73.3	Do.....	July 24	3	11	79
Do.....	Dec. 28	96	10-12	73.1	June 8	July 16	2	8	76.2
Do.....	Dec. 29	654	11-13	73.2	Do.....	July 17	15	9	76.2
Do.....	Dec. 30	712	12-14	73.2	Do.....	July 18	28	10	76.1
Do.....	Dec. 31	72	13-15	73.2	Do.....	July 19	53	11	76.1
Dec. 18-20	Dec. 29	4	9-11	73.2	Do.....	July 20	53	12	76.1
Do.....	Dec. 30	41	10-12	73.1	Do.....	July 21	5	13	76.1
Do.....	Dec. 31	415	11-13	73					

¹ At Kealakekua, Kona, Hawaii.

² At Honolulu.

While it is probable that the duration of the pupa stage in any fruit-growing section in Hawaii is never more than 20 to 28 days (average mean temperature 66.8° F.) the writers have shown that it may be much longer under cooler conditions. As a contribution toward what the maximum duration may be, the following data are presented.

In a glass refrigerator of the usual type for displaying fruits and vegetables, which was kept at a temperature of from 58 to 62° F., the duration of pupal life was found to range between 23 and 38 days when the pupæ were placed within storage within half a day after the formation of the puparium. Thus 4, 12, 9, 16, 44, 367, 1,217, 159, 25, 11, 5, 1, and 1 adults emerged in the refrigerator after 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, and 38 days, respectively, of refrigeration. One pupa 8 days old was held in storage at from 40 to 45° F. for 27 days and yielded an adult 2 days after removal to normal temperature, or 37 days after pupation. One hundred pupæ placed in a refrigerator when one-half day old and held continuously at a temperature of from 54 to 57° F. for 24 days, on removal to normal temperatures produced 2, 27, and 5 adults in 4, 5, and 6 days, respectively, after removal, or 28, 29, and 30 days after pupation. A second lot of 100 pupæ, placed at 54 to 57° F. when 1 day old, produced 3, 16, 9, 3, 2, 4, and 2 adults in refrigeration in 31, 32, 33, 34, 35, 36, 37, and 38 days, respectively, after pupation.

Pupæ formed by larvæ pupating within a refrigerator held at 52 to 56° F. yielded 2 and 1 adults within storage after refrigeration for 38 and 52 days, respectively. Out of 39,500 pupæ held in like manner at from 49 to 51° F. only 1, 2, 2, 3, and 1 pupæ yielded adults in storage after 20, 23, 44, 46, and 47 days, respectively, of refrigeration. These 9 pupæ yielding adults were 5 days old when placed in cool storage; hence they were 25, 28, 49, 51, and 52 days old when they yielded adults. One 3-day-old pupa held at an even temperature of 32° F. for 9 days, on removal to normal temperature produced an adult on November 14, 10 days later, or when 23 days old. Two 1-day-old pupæ refrigerated for 19 days and then removed to normal temperatures yielded adults in 29 and 30 days, respectively, after pupation. Investigators working in countries where the temperature falls for short periods to or slightly below freezing are referred for other data to a previous paper by the writers¹ in which are given data on the effects of 32°, 33° to 34°, 33° to 36°, 28° to 40°, 38° to 40°, 40° to 45°, 49° to 51°, 52° to 56°, and 54° to 57° F. upon 173,318 pupæ.

During January–March, 1915, the writers secured data on the effect upon the duration of pupal life of out-of-door temperatures at elevations of about 3,700 feet at Strawberry, at 5,000 feet at Puulehua, and on Mauna Hualalai at 8,250 feet. Pupæ formed at Honolulu on January 31, shipped to Kealakekua on February 9–10, and placed at Strawberry on February 11, were found to have produced 1, 72, 392, 4, and 6 adults on February 24, 25, 27, and March 3. The temperature at Strawberry for these periods ranged from 42 to 69° F. with a mean of about 56° F. Other pupæ formed at Honolulu on February 8, shipped to Kealakekua February 9–10, and placed at Strawberry February 11, were found to have yielded 3, 307, 503, and 13 adults on March 11, 17, 20, and 25, respectively. Pupæ formed at Honolulu on February 6, shipped to Kealakekua February 9–10, placed at Puulehua February 11, where the temperature between February 11 and March 26 ranged from 38° F. to 72° F., with a mean of 53° to 54° F., were found to have yielded 2, 10, 108, 126, and 13 adults on March 9, 17, 20, 25, and 26, respectively. The pupæ yielding adults on March 26 were 48 days old. Other pupæ formed at Kealakekua on January 26 and taken the same day to Puulehua yielded no adults before March 25, when they were removed to Kealakekua, where the temperature ranged during March 24–27 between 60 and 84° F. At Kealakekua 2 and 16 pupæ yielded adults on March 26 and 27, respectively, *or when 59 and 60 days old*. Pupæ formed at Honolulu February 12, shipped to Kealakekua February 17, and placed at Puulehua February 24, were found to have yielded 4, 96, and 1 adults on March 9, 17, and 20, respectively. Pupæ formed at Kealakekua January 27, taken to Hualalai January 31, and removed to Kealakekua March 26, produced no adults, and on examination appeared not to have been able actually to pupate. The temperature on Hualalai for the period ranged between 31° and 70° F. Pupæ formed at Honolulu February 9, placed on Hualalai February 12, and removed to Kealakekua March 2, yielded 10 adults between March 17 and 20, or when 36 to 39 days of age. Pupæ formed at Honolulu February 5 and taken to Hualalai February 11 were found to have yielded 51 adults between March 23 and 26. On March 26 they were removed to Kealakekua, where 17 and 2 yielded adults on March 27 and 28, respectively, or 50 and 51 days after pupation. Of this lot of pupæ, 1,820 did not survive the Hualalai temperature. Pupæ formed at Honolulu February 7, placed on Hualalai February 12, and removed to Kealakekua March 26, yielded 52 adults on March 31, or 52 days after pupation, but 1,506 failed to survive.

The data presented are of particular interest in bringing out the ability of pupæ to survive various climatic conditions apt to be experienced in countries harboring fruit flies. It will be noted that 60 days is the longest period obtained by the writers for pupal development.

¹ Back, E. A., and Pemberton, C. E. Effect of cold-storage temperatures upon the pupæ of the Mediterranean fruit fly. Jour. Agr. Research, v. 6, no. 7, 1916, p. 251–260.

THE ADULT.

DESCRIPTION.

A general idea of the relative size and coloration of the adult of the Mediterranean fruit fly may be gained by an examination of text figures 1 and 14, and Plate I figure 1, and Plate VIII figure 3. The adults vary from 3.5 to 5 mm. in length. The description by Froggatt is as follows:

Size 4 to 5 mm., about the size of an average house-fly, but looking somewhat smaller when dead, because the body shrinks up beneath the thorax. General color, ochereous yellow, lighter on the sides of thorax and basal joints of the antennae. The eyes of the usual reddish purple tint, with a blackish blotch in the center of the forehead, from which spring two stout black bristles, a fine fringe of similar bristles round the



FIG. 14.—The Mediterranean fruit fly (*Ceratitis capitata*): Adult male. Greatly enlarged. (Original.)

hind margin of the head, with some coarser ones curving round in front of the head between the eyes. The thickened basal joints of the antennae pale yellow, the terminal segments black to the tips. The dorsal surface of the thorax convex, raised, and broadly rounded with the scutellum, the ground color creamy white to yellow, marbled with shiny black blotches forming an irregular mosaic pattern, the lighter portions clothed with very fine white bristles. These light-colored bristles more lightly scattered over the dark areas, and the whole bearing large stout black bristles thickest on the black surface. In many of the pictures of this insect the black areas are drawn as if they were projecting bosses or knobs, but this is incorrect; the whole forms a regular rounded surface.

The wings are broad, semiopaque, with the extreme base blotched with ochereous or brownish yellow, with the rest of the basal area curiously marked with black, forming dark lines of the radiating nervures, with dark lines and spots between; beyond this is a broad irregular transverse ochereous band, slightly lined with black, blotched at the extremity; another similar shaped and colored blotch runs along inside but

not in contact with the costal nervure, also blotched towards the extremity in the angular space. Between these bands is another shorter black band running parallel with the first transverse band.

The oval abdomen is clothed on the upper surface with fine, scattered black bristles, and has two rather broad transverse silvery white bands on the basal half of the body. The male differs from the female in being furnished with a pair of stalked appendages standing out in front of the head in a line with the front margin of the eyes, the extremities of which filaments are produced in spatulate appendages, black, finely striated, and diamond shaped.

The living fly is an active little creature, running about over the foliage or fruit on the trees, with its wings drooping down on the sides of the body. When disturbed it has a short flight, seldom flying more than a few yards at the most, and it often returns to the same spot.

EMERGENCE.

The adults of the Mediterranean fruit fly emerge in largest numbers early in the morning during the warmer portions of the Hawaiian year, but more scatteringly during the cooler portions. During the summer the larger proportion of adults emerge between 5 and 8 a. m. On December 31, 1914, when the temperature ranged from 66° to 78° F. and the mean relative humidity was 72 per cent, 55, 58, 125, and 16 adults emerged between the hours 6 to 8 a. m., 8 to 10 a. m., 10 a. m. to 1 p. m., and 1 to 4 p. m., respectively. On January 2, 1915, when the temperature ranged from 68° to 76° F. and the relative humidity was 58 per cent, 141, 159, 28, and 12 adults emerged between the hours 6 and 8 a. m., 8 and 10 a. m., 10 a. m. and 12 m., and 12 m. and 2 p. m., respectively.

The adult when issuing from the puparium seems invariably to cause a fairly regular split from the cephalic tip of the puparium straight back along each side to near the middle of the fourth segment and then upward over the dorsum, following a line fairly well in the center of the fourth segment, and often splitting entirely around the center of this segment. Thus the upper half of the first three segments and the upper anterior half of the fourth segment of the puparium are usually broken away by the pressure of the ptilinum, and often the entire anterior portion of the puparium is broken off back to the middle of the fourth segment during the emergence of the adult.

Once out of the puparium, the adult forces its way to the surface of the soil or out of other confinement, with the aid of the ptilinum. Before the natural coloration appears and while the chitin of the body is still pliable, the adults are able to force their way through incredibly small openings or cracks, through loose cotton stoppers, and sometimes beneath rubber bands. Often the united efforts of a few adults will force an exit in places from which single adults unaided could not escape.

DURATION OF ADULT LIFE.

WITHOUT FOOD.

If adults have no opportunity to feed after emergence they die within 4 days. Ninety adults issuing on March 15 and kept under starvation conditions were all dead by the end of the third day. On the second and third days, 68 and 22 adults, respectively, died, and at 9 a. m. on the third day only 4 were barely alive, and these were dead by 5 p. m. Of 50 adults emerging on March 14, 1, 48, and 1 died on 1, 3, and 4 days later. French states that he found that adults died in Australia within 4 days if kept without food. The writers have handled many thousands of adults during the past 5 years and have never had flies live longer.

If given only water, life is slightly prolonged. Of 300 adults emerging on October 17, 250 had died by the end of the second day, while the remaining 50 were dead by the end of the third day. Of 42 adults emerging May 20, 12, 25, 4, and 1 died after 2, 3, 4, and 5 days.

WITH FOOD.

In 1899, Lounsbury in South Africa confined adult flies in a wire cage out of doors to determine the length of adult life. By the use of apples as food, 1 female out of an original number of 60 was kept alive from March 30 to July 19, or about 16 weeks. French states that adults live to be 25 days old during March in Victoria, Australia. Gurney found that in confinement adults live from a few days to three weeks. Newman states that he has found that flies live usually 6 weeks, but when no suitable food is available for oviposition, they may live from 8 to 10 weeks. Later the same writer gives the length of adult life in western Australia as ranging from 28 to 40 days in summer and from 28 to 65 days in winter.

The writers have found that even when given the best of care many adults die very young. In every lot confined in jars about 50 per cent may be expected to die during the first 2 months. The early death of many flies does not seem to be caused always by overcrowding, for frequently single adults given the best of care in separate jars die at all ages from 1 to 2 days on. The greatest interest in connection with the longevity of adults must center in the minority that live for long periods.

In a preliminary paper the writers record 1 adult that lived from December 31, 1913, to May 11, 1914, or 131 days, and others emerging on February 28, 1914, that were still alive on August 1, or 5 months after emergence. Additional data have since been secured. One female emerging on the same date died on September 4, or at the age of 5 months; another female emerging on the same date died on September 30. About 500 adults emerging on June 28 were placed in large glass jars; on August 14 only 40 were still living. The last two of these 40 adults died on October 2, at the age of 97 days. The

rate of mortality for the 40 is as follows: On August 14, 28; September 4, 9, 12, 15, 17, 19, 21, 23, 24, and October 2 and 3, there were alive 40, 30, 17, 12, 11, 10, 10, 7, 5, 4, 2, 2, 0 adults. Two hundred and twenty-five adults which emerged on December 31, 1913, were placed in a large glass jar and fed daily. The last fly which died lived to be 131 days old. A general idea of the mortality of these flies may be had from the fact that when examinations were made on March 9, 13, 18, 22, 26, 31, April 1, 6, 13, 15, 17, 18, 19, 26, 27, 28, 30, May 1, 3, 5, 7, 9, 10, and 11, there were living 225, 214, 202, 171, 139, 94, 59, 47, 36, 32, 28, 25, 18, 16, 13, 12, 11, 9, 7, 5, 4, 3, 2, and 1, respectively.

One female emerging on February 28, 1914, died on August 3; two males emerging on the same date died on October 5 (7 months, 5 days), and on October 15 (7 months, 15 days), respectively. One female emerging on March 3, 1914, died on September 8 (6 months, 3 days). The death rate among 95 males and 58 females, the only survivors on July 3 of a lot of 800 adults emerging on February 28, 1914, is given in Table XVII. The oldest fly lived 230 days, or 7 months and 10 days.

TABLE XVII.—*Data on longevity of adults of the Mediterranean fruit fly emerging on Feb. 28, 1914, which had survived until July 3.*

Date.	Adults still alive.		Date.	Adults still alive.		Date.	Adults still alive.	
	Male.	Female.		Male.	Female.		Male.	Female.
July 3	95	58	Aug. 15	19	2	Sept. 11	5	0
July 9	80	38	Aug. 18	14	2	Sept. 12	3	0
July 13	58	25	Aug. 22	11	2	Sept. 18	2	0
July 18	48	20	Aug. 25	10	2	Oct. 5	1	0
July 25	41	12	Aug. 29	9	2	Oct. 16	1	0
Aug. 1	35	6	Sept. 1	8	2	Oct. 17	0	0
Aug. 8	26	3	Sept. 8	6	0			

One female, emerging May 22, 1914, and kept continuously in a well-lighted glass refrigerator at 58°–62° F., lived until April 1, 1915, 315 days, or 10 months and 10 days. The rate of mortality of the flies still living of this lot on December 4 is recorded in Table XVIII.

TABLE XVIII.—*Data on longevity of adults of the Mediterranean fruit fly emerging on May 22, 1914, and kept in a glass refrigerator at 58°–62° F.*

Date.	Adults still alive.		Date.	Adults still alive.		Date.	Adults still alive.	
	Male.	Female.		Male.	Female.		Male.	Female.
Dec. 4	43	62	Jan. 5	17	32	Feb. 4	4	10
Dec. 15	31	55	Jan. 8	16	30	Feb. 10	1	6
Dec. 19	26	51	Jan. 13	14	28	Feb. 13	1	4
Dec. 23	24	48	Jan. 18	14	24	Feb. 17	1	3
Dec. 26	24	43	Jan. 26	9	20	Mar. 6	0	2
Dec. 29	24	37	Jan. 29	7	16	Apr. 1	0	1
Jan. 2	21	36	Feb. 1	4	12	Apr. 2	0	0

Of the adults kept at 58–62° F. the majority died after the sixth month of life, being caught by the wings in moisture gathering on the sides of the containing jars. Under more favorable conditions the writers believe that adult life may be extended to cover a full year.

MATING.

Martelli first described the mating process. He says that when the male desires to copulate he “seeks to attract the female by curving up and raising the last abdominal segment, then bending the extremity, swelling it to the form of a pinhead, while the venter is drawn back half its length and the abdomen is puffed out laterally, etc.” These evidences of sexual stimulation have been verified by the writers. In addition to the dorso-ventral contraction and lateral expansion of the abdomen, the male may vibrate his wings rapidly for periods of 10 to 15 seconds, at the same time that he extrudes the rectum (?) to form the white bulbous structure which is held almost perpendicularly over the tip of the abdomen.

Often the female will move toward the head of the male from the opposite direction to be greeted when within an inch of the male by a violent fanning of the wings of the latter. When the female is within half an inch of the male, the male moves forward in a halting fashion until the heads of each almost touch, when the male springs forward and endeavors to clasp the female, but is often repulsed. One pair were observed to go through this process five times in 30 minutes before copulation occurred. Having once placed himself, the male makes vigorous efforts to bring the tip of his abdomen in contact with the tip of the ovipositor, trying at the same time to grasp the very tip of the ovipositor with the strong chitinated claspers situated on the seventh sternite. The female need only extend the tip of the ovipositor to but a very slight degree from within the last abdominal segment and the male will quickly clasp it and draw it out to a considerable length. The operation of clasping the ovipositor and drawing it out usually takes from 10 to 20 seconds. At the end of 15 to 20 seconds, or even sooner, the long narrow ribbonlike chitinated copulatory organ begins slowly to uncoil from its position. It extends up over either the left or right side of the sixth and seventh abdominal segments and makes one, or sometimes two, loops about the distal fourth with the tip resting under the posterior edge of the fifth tergite. From this position the penis uncoils until the tip comes to a position almost between the claspers, where it enters the vaginal opening.

Both males and females mate frequently throughout life. One male was observed mating between 3 and 4 p. m., February 3, 1915, and between 11 a. m. and 12 m. and 1 and 3 p. m., February 4. Males observed mating on February 4, 1914, mated again on February 5, 6, 7, and 8. Individual females kept for oviposition records have been observed to mate frequently with the males accompanying them. Such data indicate that mating is frequent. Such frequent mating is, however, unnecessary for egg fertility, inasmuch as one female emerging August 12 and observed mating September 8 (probably not for the first time) was isolated on that date and placed with fruit. She deposited 139 eggs between September 16 and November 25, and all

hatched normally. Records on file show that the eggs deposited by 12 other females isolated after mating on September 8 hatched normally.

SEXUAL SMELL.

The writers have found that the males of the Mediterranean fruit fly emit a peculiar odor by which they may be recognized. A segregation of the sexes proved that the females do not emit this odor, or at least that no odor can be detected. That given off by the males is very evident and, while difficult of description, resembles somewhat that of stale mucus. No odor can be detected until the males begin courting the females, but from that time on it is sufficiently strong so that during calm weather a person sitting as far as 4 feet from jars containing adults is able to state whether the flies within are *Ceratitis capitata* or *Bactrocera cucurbitae*. The latter species emits no odor. The writers have attempted to make use of the odor emitted by the males to trap the females in the laboratory and field, but in no instance were females attracted to jars containing males, although the odor emanating from the latter was pronounced. Males kept at 58° to 62° F. neither courted the females nor gave off their characteristic odor.

AGE AT WHICH MATING AND OVIPOSITION BEGIN.

Adults, upon emerging from the pupa, must feed for several days before they show evidences of sexual activities or begin oviposition. Berlese, in Italy in 1905, published the first data bearing on this subject. He states that the female does not oviposit until 10 to 12 days after emergence. Severin states that in Honolulu no fully developed eggs were present in the ovaries of 3 females 8 days after emergence. Although from the eighth day on he made daily dissections of 3 females, he found no mature eggs until the fourteenth day, with the exception of a few in the ovaries of a single female 11 days after emergence. The most careful observations appear to have been made by Martelli, who states that females do not oviposit until from 4 to 7 days after emergence during summer, or 10 to 12 days during the autumn. Aside from Martelli's general reference to the season, no writer has published along with his statements data on temperatures, which the writers have found to be an important factor.

The age at which the first eggs are deposited varies with the temperature. During late July and early August, 1913, when the daily temperatures at Honolulu ranged between 74° and 86° F., with a mean for the period of 79° to 80° F., males began to show sexual activity within 3 days, while mating and egg laying took place within 4 to 5 days. In securing infestation of fruits it was found that while few eggs were deposited within 4 to 5 days after emergence, it was not until 7 to 10 days after emergence that any lot of females seemed to reach their full egg-laying capacity. These observations are based

on work with over 20,000 adults. During the period May 21 to 28, 1913, when the daily temperatures ranged between 69° and 82° F., with a mean temperature for the period of 76° F., and with a mean relative humidity about 66 per cent, many females were not observed mating until 7 to 9 days.

During the period December 14 to 24, 1914, when the weather was unusually cool for Honolulu, with the daily temperatures ranging between 61° and 78° F. (a mean for the period about 69.8° F.), and the mean relative humidity about 72 per cent, 1 male was observed giving the usual evidences of sexual maturity 8 days after emergence, and several others after 9 days. The first eggs, 3 in number, from about 150 females were obtained 8 days after emergence, while 10 and 38 eggs, respectively, were secured after 9 and 10 days. Adults emerging on January 3, 1916, did not contain well-developed eggs until 10 days later, as shown by daily

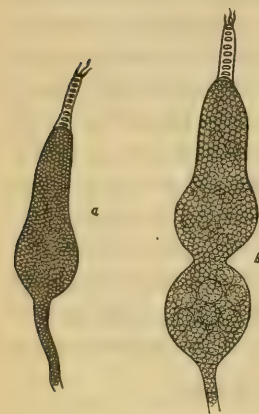


FIG. 15.—Egg tubes of female Mediterranean fruit fly: *a*, At time of emergence; *b*, 3-5 days after emergence; during January, 1916. (Original.)

dissections. The temperature during this period ranged between 60° and 75° F., with a mean of 68.7° F. The general process of egg formation as it takes place in the egg tubes is shown in figures 15 and 16, representing the development of the eggs 1, 3, 8, and 10 days after emergence.

PORTIONS OF PLANT SELECTED.

Adults of the Mediterranean fruit fly oviposit only in the fruit of the host. The female appears to have no preference for any particular area in the epidermis of very soft fruits, such as the strawberry guava, mock orange, coffee, peach, sapota, or eugenia, as egg punctures are to be found on all portions of the fruit. But even in these fruits adults oviposit most freely in prematurely ripened areas. In the case of other fruits, the epidermis of which the fly has greater difficulty in puncturing, females are apt to take advantage of previously made abrasions caused by thorn pricks, fungus attack, old egg punctures, etc. Thus the females often deposit eggs in large numbers

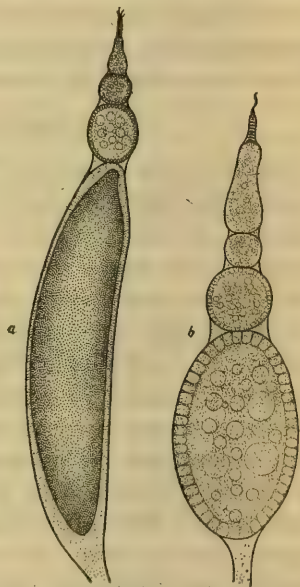


FIG. 16.—Egg tubes of female Mediterranean fruit fly: *a*, Development after 10 days; *b*, after 8 days; during January, 1916, at Honolulu. (Original.)

only in a single break made by the mango weevil or fungus attack on the skin of a large choice Indian mango. In cotton bolls eggs appear to be deposited only in breaks made by the larvæ of the pink bollworm (*Pectinophora gossypiella* Saund.). In some varieties of avocados eggs are most often deposited, in certain localities, in the cracks made by fungi, although other varieties with thinner skins are freely oviposited in at all points.

DAILY RATE OF OVIPOSITION.

No data on the daily rate of oviposition have ever been published except by the writers. In a preliminary paper they record the daily rate of oviposition during the first 18 weeks after emergence. In Table XIX these data have been continued to include the oviposition records of the same females throughout life. For the daily rate of oviposition for old females see Table XX. It will be noted that there is considerable variation in the frequency of oviposition among those specimens seemingly less hardy, but that those living longest, and apparently the most normal, oviposited with great regularity a few eggs nearly every day. The 9 females, the oviposition records of which appear in Table XIX, emerged on April 4, 1914, and were placed with fruit April 14.

The best record in Table XIX is that of fly No. 5, which oviposited with great regularity from April 16 to September 2. During life this fly oviposited on 106 days of 153. Of the 47 days on which she laid no eggs, 20 were the first 20 days of her life and 13 of these 20 were evidently consumed in reaching sexual maturity. Hence, after she began ovipositing with regularity she failed to oviposit on only 27 of 133 days. Fly No. 8, which lived 147 days, oviposited on 80 days. Fly No. 9, which lived 65 days, deposited only 3 eggs on May 4 and 5. Had it been possible to secure oviposition data on many individuals it is probable that the record of fly No. 5 would have been exceeded and that many gradations would have been secured between the records of flies Nos. 5 and 9. This is probable, inasmuch as other females recorded under the subject of longevity lived to be over 10 months old, and there is no evidence that oviposition necessarily ceases before death. It is not likely, however, that the actual number of eggs deposited on individual days would have been found greater than those recorded in Table XIX. This actual number of eggs deposited on individual days was found to vary from 1 to 22. The average numbers of eggs deposited by the 9 females, taking into consideration only the days on which oviposition occurred, are 6.6, 3.1, 5.7, 7.5, 5.9, 6.1, 5.9, 5.2, and 1.5. Flies Nos. 5 and 8, which lived the longest, deposited, respectively, an average of 5.9 and 5.2 eggs.

TABLE XIX.—*Daily rate of oviposition of the Mediterranean fruit fly in 1914.*

[Females emerged on Apr. 4, 1914, and were placed with fruit on Apr. 14, 1914.]

Date of oviposition. ¹	Number of eggs deposited.								
	Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.	Fly No. 7.	Fly No. 8.	Fly No. 9.
Apr. 16.....	3	0	0	0	0	0	0	0	0
17 to 20.....	14	7	11	24	19	14	0	0	0
20 to 22.....	0	0	0	0	0	5	0	0	0
22 to 24.....	0	0	7	0	0	0	0	2	0
25 to 26.....	0	7	13	0	13	0	14	0	0
27 to 28.....	11	8	6	0	16	15	0	20	0
29 to 30.....	0	0	0	0	17	16	23	0	0
May 1 to 3.....	0	0	0	3	25	19	19	13	0
4 to 5.....	25	0	0	0	12	0	0	0	3
6.....	2	0	0	0	0	0	9	0	0
7.....	8	0	0	0	19	12	2	8	0
8.....	9	0	0	0	9	3	1	0	0
9.....	9	0	0	0	7	7	4	3	0
10.....	0	0	0	2	0	6	2	0	0
11.....	17	0	0	0	7	3	0	0	0
12.....	4	4	0	0	10	4	8	0	0
13.....	14	0	0	0	7	8	11	0	0
14.....	8	4	0	0	10	2	9	0	0
15.....	8	0	0	5	5	6	6	1	0
16.....	5	0	0	0	11	6	8	14	0
17.....	8	0	0	0	0	4	3	0	0
18.....	2	0	0	13	3	3	3	8	0
19.....	3	4	0	0	5	0	3	9	0
20.....	2	(²)	0	0	6	9	3	11	0
21.....	0	.....	0	0	2	2	9	8	0
22.....	5	.....	0	0	5	0	1	9	0
23.....	10	.....	20	4	6	10	4	4	0
24.....	4	.....	2	18	3	1	4	7	0
25.....	5	.....	19	4	2	3	3	3	0
26.....	0	.....	2	9	6	2	0	3	0
27.....	0	.....	6	15	9	0	5	8	0
28.....	0	.....	(³)	3	3	5	3	4	0
29.....	9	.....	.....	9	3	14	7	7	0
30.....	1	.....	.....	12	0	8	10	4	0
31.....	0	.....	.....	9	6	13	21	8	0
June 1.....	0	.....	.....	8	3	10	5	5	0
2.....	0	.....	.....	13	5	6	14	6	0
3.....	0	.....	.....	9	12	4	7	2	0
4.....	5	.....	.....	3	3	4	3	9	0
5.....	0	.....	.....	7	8	0	6	5	0
6.....	0	.....	.....	4	6	0	4	3	0
7.....	0	.....	.....	18	11	15	15	12	0
8.....	0	.....	.....	0	0	1	0	1	0
9.....	0	.....	.....	15	7	8	12	9	0
10.....	0	.....	.....	6	5	11	1	2	(⁴)
11.....	0	.....	.....	12	7	11	9	6	.....
12.....	(⁴)	.....	.....	0	6	3	3	6	.....
13.....	.....	.....	.....	7	2	7	7	0	.....
14.....	.....	.....	.....	4	7	2	1	8	.....
15.....	.....	.....	.....	0	7	4	5	2	.....
16.....	.....	.....	.....	0	9	4	5	3	.....
17.....	.....	.....	.....	0	6	0	0	2	.....
18.....	.....	.....	.....	0	0	0	0	3	.....
19.....	.....	.....	.....	0	6	3	3	8	.....
20.....	.....	.....	.....	4	4	12	4	4	.....
21.....	.....	.....	.....	10	10	7	0	9	.....
22.....	.....	.....	.....	4	0	0	0	5	.....
23.....	.....	.....	.....	10	2	(⁵)	0	0	.....
24.....	.....	.....	.....	0	9	.....	12	12	.....
25.....	.....	.....	.....	0	7	.....	3	3	.....
26.....	.....	.....	.....	0	9	.....	0	2	.....
27.....	.....	.....	.....	5	6	.....	7	4	.....
28.....	.....	.....	.....	16	14	.....	12	4	.....
29.....	.....	.....	.....	6	5	.....	0	2	.....
30.....	.....	.....	.....	0	2	.....	6	2	.....
July 1.....	.....	.....	.....	3	7	.....	2	8	.....
2.....	.....	.....	.....	10	0	.....	7	1	.....
3.....	.....	.....	.....	3	0	.....	3	1	.....
4.....	.....	.....	.....	7	4	.....	8	6	.....
5.....	.....	.....	.....	0	6	.....	2	3	.....
6.....	.....	.....	.....	0	3	.....	4	0	.....

¹ Dates on which none of the flies oviposited are omitted from the table.² Died on this date; 30 eggs present in abdomen.³ Escaped on this date.⁴ Died on this date.⁵ Died on this date; 15 eggs present in abdomen.

TABLE XIX.—Daily rate of oviposition of the *Mediterranean fruit fly* in 1914—Contd.

Date of oviposition.	Number of eggs deposited.								
	Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.	Fly No. 7.	Fly No. 8.	Fly No. 9.
July 7.....				0	2		0	0	
8.....				(1)	3		9	2	
9.....					6		3	4	
10.....					2		3	4	
11.....					0		8	2	
12.....					9		4	0	
13.....					2		0	0	
14.....					5		3	5	
15.....					2		0	3	
17.....					4		0	0	
19.....					0		0	4	
20.....					0		2	0	
22.....					14		0	0	
23.....					0		3	0	
24.....					11		4	0	
25.....					7		7	0	
26.....					11		0	3	
27.....					5		0	0	
28.....					2		3	0	
29.....					3		0	0	
30.....					2		0	2	
31.....					6		0	6	
Aug. 1.....					3		0	4	
2.....					7		(2)	4	
3.....					4			2	
5.....					5			5	
6.....					2			5	
7.....					3			0	
8.....					0			2	
9.....					4			0	
10.....					6			0	
13.....					14			14	
14.....					3			3	
15.....					0			13	
16.....					4			0	
17.....					3			6	
18.....					5			0	
19.....					2			0	
21.....					4			0	
25.....					3			0	
27.....					3			0	
28.....					6			0	
29.....					3			0	
30.....					0			(3)	
Sept. 2.....					3				
4.....					(4)				
Total.....	191	34	86	314	622	312	426	405	3

¹ Died on this date; 16 eggs present in abdomen.² Died on this date; no eggs in abdomen.³ Died on this date; 2 eggs in abdomen.⁴ Died on this date; 3 eggs in abdomen.

ABILITY OF FEMALES TO BEGIN OVIPOSITING REGULARLY AFTER A PERIOD OF SEVERAL MONTHS DURING WHICH HOST FRUITS WERE NOT AVAILABLE.

Females which have been kept in confinement without an opportunity to oviposit in host fruits will begin actively ovipositing when such fruits are made available. Thus, females emerging on February 28, 1914, were kept in glass jars until about 4 months old, when, on June 28, they were placed with fruits and a record kept of the eggs deposited. These data secured from 6 females show that for the days on which they oviposited they laid an average of 8.1, 4.6, 0, 6.3, 4, and 7.2 eggs. These averages compare favorably with the averages for females given an opportunity to oviposit from the time they were sexually mature until death. Fly No. 1, with its average of 8.1 eggs, deposited 22 eggs on July 26, or when it was

148 days old, and this is the largest number of eggs ever obtained by the writers during one day from any female. The flies of Table XX oviposited on the sides of their containing jars during the period up to the time they were given fruits in which to deposit eggs, but not in a normal manner.

TABLE XX.—*Daily rate of oviposition of the Mediterranean fruit fly.*

[Females emerged on February 28, 1914; hence were 4 months old on June 28, 1914. Given an opportunity to oviposit on fruit for first time on July 1.]

Date. ¹	Number of eggs deposited.						Date. ¹	Number of eggs deposited.					
	Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.		Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.
1914.							1914.						
July 1.....	0	0	0	0	6	0	July 19.....	6	2	.....	0	0	.....
2.....	9	0	0	0	2	0	20.....	0	5	.....	4	0	.....
3.....	0	0	0	0	4	0	21.....	5	2	.....	6	0	.....
4.....	10	4	0	0	0	6	22.....	0	8	.....	7	0	.....
5.....	4	0	0	0	0	0	23.....	0	2	.....	0	0	.....
6.....	5	6	0	4	0	0	24.....	2	6	.....	13	(4)	.....
7.....	0	0	0	0	0	12	25.....	6	2	.....	0	0	.....
8.....	10	6	0	0	0	6	26.....	22	1	.....	0	0	.....
9.....	0	4	0	9	0	13	27.....	9	2	.....	0	0	.....
10.....	15	6	0	3	0	2	28.....	9	0	.....	5	0	.....
11.....	5	2	0	0	0	4	29.....	6	7	.....	0	0	.....
12.....	12	7	(2)	5	0	(2)	30.....	0	5	.....	0	0	.....
13.....	12	0	.....	5	0	.....	Aug. 1.....	0	(5)	.....	0	0	.....
14.....	7	9	.....	0	0	.....	2.....	0	.....	.....	0	0	.....
15.....	0	8	.....	0	0	.....	3.....	(6)	.....	(2)	.....	.....	.....
16.....	13	3	.....	11	0	.....							
17.....	5	0	.....	4	0	.....	Total..	162	97	0	76	12	43
18.....													

¹ Dates on which none of the flies oviposited are omitted from the table.

² Died on this date; no eggs in abdomen.

³ Died on this date; 11 eggs in abdomen.

⁴ Died on this date; 5 eggs in abdomen.

⁵ Died on this date.

⁶ Died on this date; 4 eggs in abdomen.

One female emerging March 3, 1914, was isolated from fruits until August 29, or for 5 months and 26 days. When placed with fruit on August 29 she deposited 4, 5, 11, 14, 9, and 9 eggs on August 31, September 3, 4, 5, 6, and 7, or an average of 8.7 eggs for each day on which she oviposited. She deposited 11, 14, 9, and 9 eggs, respectively, on the first 4 days of the seventh month of her life, but died on the fifth day.

NUMBER OF EGGS DEPOSITED BY SINGLE FEMALES.

No attempts have been made by previous writers to determine the egg-laying capacity of the female. In 1906 Fuller assumed as a basis for data on multiplication that each female deposited 50 eggs at one time. Silvestri, after becoming familiar with the work of the writers while in Honolulu, stated that the total number of eggs deposited is not less than 300. In general, entomologists invariably have used the number of eggs found in the body as a basis for computing the egg-laying capacity.

In Table XIX the only data obtained by the writers on this subject show that the total number of eggs deposited by a single female

may be as high as 625. Fly No. 5 deposited 622 eggs and held 3 well-formed eggs in her oviducts at death. Fly No. 9, on the other hand, deposited only 3 eggs during her life. The writers believe that hardy females may deposit as many as 800 eggs, or even more, under favorable conditions. Fly No. 5, which deposited 622 eggs, lived only 153 days, while other females have oviposited for periods covering more than 10 months and might be expected to deposit more eggs. As noted above, one female deposited 11, 14, 9, and 9 eggs during the first 4 days of the seventh month of her life.

NUMBER OF EGGS DEPOSITED AT ONE TIME.

During the period from January 23 to 27, 1914, when the temperatures during the heat of the day ranged between 74° and 76° F., 15 females were observed to oviposit in apples. The time required from the instant the females started ovipositing until the ovipositor was withdrawn varied from 2 to 5 minutes, with an average of 3.8 minutes. Each puncture was found to contain from 1 to 4 eggs, and averaged 2.4 eggs.

During the warmer period of the year, on April 13, 1914, when the temperature averaged about 82° F., 8 females consumed from 2.5 to 4.5 minutes in completing the process of oviposition in apples, and deposited from 3 to 9 eggs, or an average of 5.4 eggs in each puncture.

NUMBER OF EGGS DEPOSITED IN A SINGLE EGG CAVITY.

Females oviposit repeatedly in egg cavities or punctures in table fruits, especially in those fruits in which they have difficulty in making egg chambers. Thus while females, as already noted, deposit normally only from 3 to 9 eggs in a puncture in apples at one time, cavities in apples left with females from 3 p. m. until the following morning contained from 42 to 106 eggs. As many as 300 eggs have been taken from one egg cavity in the rind of grapefruit, 129 from a cavity in a lemon, and 926 from a cavity in a mango. (Pl. XIII, fig. 3.) Observations indicate that after depositing a few eggs the females feed and move about only to return in many instances to the same spot to continue ovipositing. Frequently newly laid eggs can be found in punctures in citrus fruits in which several batches of eggs already have been hatched. Bearing in mind that only from 1 to 9 eggs are usually deposited in an egg cavity at one time, the data in Table XI will prove interesting.

OVIPOSITION BY VIRGIN FEMALES.

Females confined in jars immediately after emergence and given no opportunity to mate will deposit eggs, but none of the eggs will hatch. On September 10, 1913, 500 newly emerged virgin females were placed in a jar and began ovipositing in a normal manner on September 16, or after 6 days. One hundred and twenty-eight eggs

deposited September 16 did not hatch. The temperature during this period varied between 71 and 84° F., with a mean for the period of 78.5° F., and the relative mean humidity averaged about 66 per cent. Two hundred females emerging November 13, 1914, were confined without males and began ovipositing November 23, or after 10 days. During this period the temperature ranged between 65 and 80° F., with a mean of 74.6° F.; the relative humidity, averaging 69.2 per cent, ranged between 52 and 85 per cent. Although no daily oviposition records of these females were kept, 450 eggs deposited by them in apples on 17 different occasions when they were given an opportunity to oviposit between November 13 and March 4-5 failed to hatch. In three other experiments not one of 2,264 eggs deposited by virgin females hatched.

Virgin females which have been depositing eggs that failed to hatch may mate later and deposit fertile eggs. Thus 200 virgins emerging on March 13, 1915, oviposited quite regularly until May 14, when males were placed in the jar with them. Previous to May 14 all eggs deposited had failed to hatch. On May 16, 11 eggs were deposited; of these all hatched but 2.

INFLUENCE OF WEATHER CONDITIONS ON ADULT ACTIVITIES.

No satisfactory data on this subject can be secured out of doors in the Hawaiian Islands, as the colder temperatures which seriously affect adult activities are not to be had except at higher altitudes, where the fly is not to be found. At the Volcano House, Hawaii, at about 4,000 feet elevation, where the November mean is about 60° F. and the daily range is between 45° and 72° F., adults in jars were inactive during the early mornings and late afternoons. During the warmer period of the day adults became active and oviposited in apples hung in their jars after the temperature reached 61° F. At Honolulu, at a temperature of 65° to 67° F., 27 eggs were deposited in peaches by about 40 females, and 40 eggs by a lot of 60 females. At higher temperatures many more eggs would have been deposited under otherwise similar conditions. Adults in jars were noted to mate as usual on March 17, when the temperature was 69° F. On March 18, 9 a. m., at 67° F., adults endeavored to oviposit in apples, but did not seem to succeed in puncturing the skin. A female emerging on August 12, 1914, was placed in a large glass refrigerator, the temperature of which averaged 61° F., but varied for the period between 58° and 62° F. She was accompanied by males and deposited 3 and 6 eggs on September 12 and 20, respectively, but died on September 25. This fly was replaced by another of like age, which deposited 9, 5, 8, 4, and 6 eggs, respectively, on September 26, 27, 28, 29, and October 2.

At a mean temperature of about 78° F., adults may deposit eggs during the night, but deposition during this portion of the day has

been found most unusual. In the laboratory and out of doors adults feed and oviposit at all times of the day during the warmer months. Lounsbury has stated that in South Africa adults seek shelter beneath dried leaves, etc., in rearing cages during the colder weather, and Compere has observed adults active on orange trees in Spain during the warm hours of a day following freezing night temperatures.

LENGTH OF LIFE CYCLE.

During the warmest Hawaiian weather, when the mean temperatures average about 79.5° F., the egg, larva, and pupa stages may be completed in as few as 13 or as many as 33 days, according to the individual and its host. At this season large numbers pass through the immature stages in from 18 to 20 days. As the length of the adult life has been found to vary from a few days to 230 and 315 days, it is evident that the life cycle may be as long as 11 months when the fly passes its immature stages during the warmest portions of the year. At an average mean temperature of about 68° F., which is the coolest mean found by the writers where host fruits were readily available for study, the immature stages required from 40 to 69 days. Data already discussed indicate the difficulty in stating just what variations there may be in the length of the life cycle in still cooler climates. Thus the egg stage has been increased from 2 to 24 or 25 days by the application for 22 days of a temperature of from 48° to 53° F. A third-stage larva survived a temperature of 48° to 54° F. for 79 days, while another larva remained in the first instar 57 days at an out-of-door temperature ranging from 27° to 73° F., with a mean of about 48° F. The fruit fly has been held in the pupa stage at an out-of-door temperature ranging between 38° and 72° F., with a mean of about 53° to 54° F. for about 2 months. At Kealakekua, where the temperature ranged between 58° and 80° F., with a mean of about 68° F., 3 larvæ in very firm apples required 28, 58, and 74 days to become fully mature and leave the fruit to pupate. Add to the 74 days required for larval maturity 4 days for the egg stage and 20 days for the pupa stage, and one has a cycle for these stages of 98 days, or over 3 months. A very conservative estimate for the possible length of the immature stages, or a period sufficiently long to outlast the coldest seasons of semitropical regions, is 3 to 4 months.

SEASONAL HISTORY.

In littoral Hawaii there may be as many as 15 or 16 generations of the Mediterranean fruit fly each year, provided one considers the length of a generation as extending from the time the eggs are deposited until the female of the next generation begins to oviposit. With such an understanding a generation at Honolulu may require under the most favorable conditions as few as 17 days during the warmest weather, or as few as 31 days during the coolest winter

weather. As the females are capable of living long periods and of depositing small batches of eggs almost daily, the generations become hopelessly confused. In those portions of the islands where the winter monthly means drop to about 68° F., as in the Kona district of Hawaii at about 1,300 feet elevation, there may be not more than 10 to 12 generations. The number of generations is naturally less in colder habitats. At Strawberry, a ranch station on Hawaii at about 4,500 feet elevation, there appears to be only a single generation a year, which is evident in the last fruit to ripen on a few peach trees.

As may be expected, adults are abundant at all seasons in the littoral regions of Hawaii where host plants are grown. With the hopeless confusion of generations that exists, there can be no seasonal broods. Instead, adults may be found actively ovipositing every day of the year. That the cooler weather of the winter months does lengthen the life cycle has already been proved. This slowing down of development naturally results in the emergence of fewer adults. This is indicated by the data of Table XXI.

TABLE XXI.—*Seasonal abundance of adult Ceratitis capitata at Honolulu.*

[Average daily catch of 147 kerosene traps for the weeks indicated below, from Apr. 21, 1913, to Aug. 4, 1914.
Traps exposed in Punahou district of Honolulu, east of Punahou Street and south of Wilder Avenue.]

Date.	Num- ber.	Date.	Num- ber.	Date.	Num- ber.	Date.	Num- ber.	Date.	Num- ber.
Apr. 26..	279	Aug. 2....	905	Nov. 8....	353	Feb. 13....	58	May 23....	291
May 3....	347	Aug. 9....	937	Nov. 15....	237	Feb. 20....	117	May 30....	259
May 10....	677	Aug. 16....	763	Nov. 22....	137	Feb. 28....	64	June 6....	389
May 17....	901	Aug. 23....	562	Nov. 29....	132	Mar. 7....	71	June 13....	729
May 24....	1,738	Aug. 30....	439	Dec. 6....	219	Mar. 14....	49	June 20....	1,074
May 31....	1,498	Sept. 6....	316	Dec. 13....	324	Mar. 21....	74	June 27....	935
June 7....	1,413	Sept. 13....	219	Dec. 19....	355	Mar. 28....	64	July 4....	1,676
June 14....	1,047	Sept. 20....	152	Dec. 27....	240	Apr. 4....	92	July 11....	2,503
June 21....	855	Sept. 27....	141	Jan. 2....	176	Apr. 11....	123	July 18....	2,002
June 28....	1,084	Oct. 4....	167	Jan. 9....	48	Apr. 18....	150	July 25....	1,677
July 5....	769	Oct. 11....	200	Jan. 16....	84	Apr. 25....	124	Aug. 1....	964
July 12....	723	Oct. 18....	200	Jan. 24....	46	May 2....	188	Aug. 4....	523
July 19....	769	Oct. 25....	205	Jan. 31....	51	May 9....	343		
July 26....	727	Nov. 1....	270	Feb. 7....	72	May 16....	455		

These data on the number of males captured in 147 traps in an area equal to about four city blocks are taken as indicating the relative abundance of adults in a single year, in a section of Honolulu where many host trees occur. The adults are most numerous during late May, June, and July, and less numerous during January, February, and March. The numerical abundance of adults in Honolulu, where the climate never seriously retards development, is affected more by the numerical abundance of ripening host fruits, which is greatest during the early summer and least during the winter. The fact that there are relatively fewer adults during the winter months is of no practical value to growers of fruit in Hawaii, since the smaller amount of fruit ripening at that season is nearly as badly affected as are the fruits ripening during the summer.

NATURAL CONTROL.

No striking examples of control by natural agencies were evident in Hawaii previous to the introduction of parasites. As indicated below, there are several minor factors of natural control, aside from parasites, but they are of no practical value under Hawaiian conditions. A certain amount of natural mortality occurs among larvæ and pupæ, but it is small under ordinary conditions. It has been suggested that there occurs an unusually high mortality among pupæ formed by larvæ developing in such juicy fruits as the mango, but this has been disproved by experimental work. The high rate of mortality among pupæ derived from mangoes in laboratories is produced by the severe sifting process necessary to separate the pupæ from the wet sand in which they form, or from insanitary conditions.

EXCESSIVE HEAT.

The larvæ within fruits which lie in the direct sunlight after they have fallen are killed in large numbers. Often all the larvæ in the portion of a fruit exposed to the sun will be found dead. During August, 1914, mangoes were exposed to the sun for two days over sand in shallow trays. Examinations later proved the 17 fruits to contain 17 living and 84 dead third-instar larvæ, with 14 larvæ dead on the surface of the fruits. One larva died when partly out of a fruit and 103 succeeded in pupating normally. In 23 other fruits held in the shade as a check there were found 168 living and 9 dead third-instar larvæ, and beneath them 167 pupæ. While every larva in certain of the fruits exposed to the sun was killed, it is evident the many larvæ in the protected portion of the fruit may escape and pupate normally.

PREDACIOUS ENEMIES.

Although Compere reported certain staphylinid beetles in Brazil and forficulids in India attacking larvæ of fruit flies, they seem to be of little value as practical checks. The writers have observed earwigs within decayed areas of fruits infested by *C. capitata* and drosophilid larvæ in Hawaii under conditions which indicated that they were feeding upon fruit-fly larvæ. Earwigs confined in jars within the laboratory were observed to attack and devour well-grown *C. capitata* larvæ. Their numbers, however, are far too small to have any effect upon fruit-fly increase..

The small brown ant (*Pheidole megacephala* Fab.), known also as the Madeira house ant and the harvester ant, unquestionably is an important factor in natural control. This ant, which inhabits most abundantly the littoral regions, is frequently found swarming over and throughout fallen fruits, killing many larvæ as they leave the fruit to pupate. Ants were observed to remove from a fallen ball kamani nut 86 medium sized *C. capitata* larvæ between 11.18 and 11.58 a. m., April 5, 1913. An examination at the end of this period

This conclusion drawn from cold-storage experiments¹ will be found, the writers believe, to hold true for out-of-door conditions. During January to March, 1914, the writers exposed infested apples on the slopes and summit of the extinct volcano Hualalai, at elevations of about 5,000 and 8,250 feet. At about 5,000 feet elevation, where the temperature ranged from 31° to 64° F., during January, with a mean of about 51° F., the larval development was apparently held at a standstill, although as the minimum temperatures increased with the approach of spring, larvæ were able to more than hold their own. During March, when the daily temperatures ranged from 40° to 70° F., with a mean of about 55° F., development of all stages occurred attended by no unusual mortality. At 8,250 feet elevation, where the minimum temperatures ranged from 27° to 43° F., with the maximums between 42° and 70° F., and a mean for the maximums and minimums of about 48° F., no development took place. Instead, the mortality was very great. As spring approached, the temperatures increased until, during March 20 to 25, they ranged between 38° and 67° F. The result of examinations made of infested apples after indicated periods of exposure are given in Table XXIII.

TABLE XXIII.—*Mortality among eggs and larvæ of the Mediterranean fruit fly in apples exposed on the summit of Hualalai from Jan. 31 until date of removal.*

Fruit removed from mountain.	Date of examination.	Eggs unhatched.	Larvæ.					
			First instar.		Second instar.		Third instar.	
			Alive.	Dead.	Alive.	Dead.	Alive.	Dead.
Feb. 4.....	Feb. 5	.....	221	1	.....	.....	.....	.....
Feb. 12.....	Feb. 15	.....	334	20	522	82	33	.....
Feb. 17.....	Feb. 19	5	3	115	97	16	2	.....
Feb. 25.....	Feb. 26	28	27	350	37	434	3	154
Mar. 4.....	Mar. 6	10	55	481	33	216	.....	.....
Mar. 17.....	Mar. 19	2	3	315	.....	278	6	500
Mar. 26.....	Mar. 27	24	1	872	2	56	2	965

These data prove that at the Hualalai temperatures a very few larvæ may survive, although by far the largest percentage are killed.

The data given elsewhere (p. 108-111) on the effect of cold storage and freezing temperatures upon the various stages of the fruit fly prove how easily this pest can withstand for short intervals colder temperatures than are likely to occur for long periods in fruit-fly countries. Thus the egg itself has been known to withstand a freezing temperature of from 24° to 30° F. for 7 days and still hatch. These low temperatures, however, produce a very great mortality that has been emphasized by data already published.

That adverse climatic conditions have been a valuable aid in curbing fruit-fly attack is appreciated by entomologists dealing with this

¹ See Journal of Agricultural Research, v. 5, 1916, p. 657-666; v. 6, 1916, p. 251-260.

pest. Newman, in Western Australia, has found that a very large percentage of the pupæ are killed by a cold, wet winter when the ground is frequently flooded. Such conditions so lessen the abundance of the fruit-fly that there are relatively few flies, numerically speaking, to infest the early fruits of the succeeding season. On the other hand, unusually severe outbreaks of the pest in both South Africa and Australia have been attributed to exceptionally dry, mild winters which made it possible for many adults to be present the following spring to start large early summer generations. The successes attributed to clean cultural methods for the eradication of the fruit fly in the apple orchards at Harvey, Western Australia, and possibly in New Zealand and Tasmania, may be due quite as much to the work of adverse climatic conditions. The effect of climate upon fruit-fly development can not be intelligently interpreted, inasmuch as previous writers have not included climatological data with their statements.

PARASITES.

CERATITIS AND DACUS PARASITES.

Literature contains numerous references to parasites reared from various species of fruit flies. The only parasites discussed at length here are those which have been successfully introduced and give promise of being useful as factors in controlling *Ceratitis capitata*. Of the parasites at present being reared from *Ceratitis capitata* under natural conditions, *Opius humilis* is the only one reared originally from this fruit fly.¹ All other parasites now known to attack *Ceratitis capitata* in the field in Hawaii have adapted themselves to this host. There appears to be no reason why certain others of the parasites already reared from other fruit flies may not be used ultimately in controlling the Mediterranean fruit fly. Silvestri records and discusses the following parasites studied by him:

BRACONIDÆ.

Subfamily Opiinae: *Opius concolor* Szepligeti (ex *Dacus oleae*, Susa, Tunisia), *O. dacicida* Silvestri (ex *Dacus oleae*, Eritrea), *O. lounsburyi* Silvestri (ex *Dacus oleae*, Transvaal), *O. dexter* Silvestri (ex *Dacus longistylus*, Dakar, Senegal), *O. perproximus* Silvestri (ex *Dacus brevistylus* and *Ceratitis giffardi*, Kotonou and Segborou, Dahomey), *O. perproximus modestior* Silvestri (ex *Ceratitis nigerrima* Aburi, Gold Coast, and Olokemeji, Nigeria), *O. humilis* Silvestri (ex *Ceratitis capitata*, Constantia, Cape Colony), *O. inconsuetus* Silvestri (ex *Ceratitis tritea*, Olokemeji, Nigeria), *O. inquirendus* Silvestri (identity of host unknown, Victoria, Kamerun), *O. africanus* Szepligeti (ex *Dacus oleae*, South Africa and Transvaal), *O. africanus orientalis* Silvestri (ex *Dacus oleae*, Eritrea), *Hedylus giffardii* Silvestri (ex *Ceratitis punctata*, Conakry, French Guinea), *Diachasma fullawayi* Silvestri (ex *Ceratitis giffardi* and *tritea*, Dakar, Senegal, Olokemeji, Nigeria, and Kakoulima, French Guinea), *D. fullawayi robustum* Silvestri (ex *Dacus bipartitus*,

¹ The writers reared a single specimen of a parasite from a *C. capitata* pupa which was identified by D. T. Fullaway as *Spalangia* sp. It seems probable that this was primarily a parasite of some other dipteran, as no other specimens were reared.

Conakry, French Guinea), *D. tryoni* Cameron (ex *Bactrocera tryoni*, New South Wales and Queensland, Australia), *Biosteres caudatus* Szepligeti (ex *Ceratitis giffardi*, tritea, nigerrima, anonae, antistictica, and *Dacus bipartitus* and *brevistylus*, West Africa).

Subfamily Sigalphinae: *Sigalphus daci* Szepligeti (ex *Dacus oleae*, Transvaal).

Subfamily Braconinae: *Bracon celer* Szepligeti (ex *Dacus oleae*, Stellenbosch and Wellington, South Africa).

PROCTOTRUPIDAE.

Subfamily Diapriinae: *Galesus silvestrii* Kieffer (ex *Ceratitis anonae*, Olokemeji, Nigeria; ex *C. nigerrima*, Aburi, Gold Coast; ex *C. giffardi*, Kotonou, Dahomey), *G. silvestrii robustior* Silvestri (ex *Ceratitis punctata*, Oonakry, French Guinea), *Trichopria capensis* Kieffer (ex *C. capitata*, Constantia, Cape Colony).

CHALCIDIDAE.

Subfamily Chalcidinae: *Dirhinus giffardii* Silvestri (ex *Ceratitis anonae*, Olokemeji, Nigeria), *D. ehrhorni* Silvestri (ex *Ceratitis giffardi*, Olokemeji, Nigeria).

Subfamily Pteromalinae: *Spalangia afra* Silvestri (ex *Ceratitis anonae*, Olokemeji, Nigeria).

Subfamily Eulophinae: *Tetrastichus giffardii* Silvestri (ex *Ceratitis antistictica*, *giffardi*, *colae*, and *Dacus bipartitus*, West Africa), *T. oxyurus* Silvestri (ex *Ceratitis tritea*, Olokemeji, Nigeria), *T. giffardianus* Silvestri (ex *Ceratitis giffardi*, Nigeria and Dahomey), *T. dacioides* Silvestri (ex *Dacus bipartitus*, West Africa), *Syntomosphyrum indicum* Silvestri (ex *Dacus*, India).

In addition to these, Ithering records the following parasites from Brazilian fruit flies: *Eucola* (*Hexamerocera*) *brasiliensis* Ashmead, *Biosteres brasiliensis* Szepligeti, *B. areolatus* Szepligeti, *B. sp.*, and *Opiellus trimaculatus*. Gowdey states that he reared a single chalcidid parasite from *C. capitata* pupæ in one out of many attempts to secure parasites.

To the foregoing list of fruit-fly parasites should be added *Pachycrepoides dubius*, introduced by D. T. Fullaway at Honolulu from the Philippines during the early part of 1914. Although a parasite of a dung fly (species not recorded) and introduced to aid in the control of the horn fly, it has since been reared from *C. capitata* pupæ by the writers.

GENERAL HISTORY OF PARASITE INTRODUCTIONS.

Attempts have been made to introduce fruit-fly parasites to control *Ceratitis capitata* from India into Western Australia by Compere, from India into South Africa via Western Australia by Lounsbury, from India into Italy by Silvestri, from Brazil into South Africa by Lounsbury and Fuller, and from Africa and Australia into the Hawaiian Islands by the Hawaiian Board of Agriculture and Forestry. So far as is at present known, these attempts have failed in all countries except in the Hawaiian Islands. Compere arrived at Perth, Australia, on December 7, 1907, with fruit-fly pupæ secured at Bangalore, India. Although he reared from these pupæ an estimated 2,000,000 specimens of *Syntomosphyrum indicum* and 300 specimens representing two braconid species and was able to make numerous liberations in badly affected areas, the West Australian

fruit growers have received no appreciable benefit. Newman, in 1908, stated that he had collected in the field during that year pupæ of *C. capitata* parasitized by the introduced parasites. In 1909 he stated, however, that the chalcid and braconid parasites, although liberated for over 15 months, had not yet produced evident results, and in 1911 he wrote that although *Syntomosphyrum indicum* had been reared and liberated in large numbers during the previous four years, it did not appear to be established and there seemed little prospect of favorable results.

In 1905 Lounsbury and Fuller investigated fruit-fly conditions in Brazil and secured parasitized pupæ of *Anastrepha fratercula*, but they were unable to reach South Africa with living parasites. Parasitized pupæ of *C. capitata* were sent from Western Australia to Durban and Cape Town during 1908, but Lounsbury reported in 1909 that the introduction was unsuccessful. Silvestri, on his return in 1913 to Hawaii from West Africa, left in South Africa specimens of *Dirhinus* and *Galesus*, but they were unable to survive the following winter according to Lounsbury. Silvestri states that although he introduced *Syntomosphyrum indicum* into Calabria, Italy, he had not been able to prove that it had become established.

INTRODUCTION OF PARASITES INTO HAWAII.

The search for and discovery, the introduction, and subsequent establishment of parasites of *Ceratitis capitata* in the Hawaiian Islands form an interesting and important chapter in the history of this world-wide pest. The writers are able to state definitely, as a result of their biological work between September, 1912, and May, 1913, that no parasites of *Ceratitis capitata* were present in Hawaii up to the time when the first introductions were made in May, 1913, if we except the *Spalangia* sp. referred to on page 80 (footnote). At the present time, January 1, 1916, all larval parasites (*Opius humilis*, *Diachasma tryoni*, *D. fullawayi*, and *Tetrastichus giffardianus*) that have been liberated are being recovered in the field, and practically every lot of larvæ reared from samples of fruit collected in the littoral regions are found to be parasitized by one or more parasites. From exceptional lots all four parasites have been reared. The two pupal parasites, the procototrupid *Galesus silvestrii* and the chalcid *Dirhinus giffardii*, have never been recovered by the writers and will not be the subject of further discussion.

The parasites at present attacking *Ceratitis capitata* in Hawaii have been introduced by the Hawaiian Board of Agriculture and Forestry. Much credit is due Mr. W. M. Giffard, who, as president of this board, was able to make arrangements for the Silvestri and the Fullaway-Bridwell expeditions to Africa. Dr. Silvestri set out from Italy during

July, 1912, and arrived at Honolulu May 16, 1913. During this time he searched for parasites in the West African States of Senegal, French Guinea, Nigeria, Kamerun, Gold Coast, Dahomey, the Kongo, and Angola; also in South Africa and in Australia. It is needless to say that Dr. Silvestri was unable to make a complete survey of fruit-fly conditions during so short a time, yet his investigations were successful, not only because they cleared the way for the Fullaway-Bridwell expedition, but also because they resulted in the introduction and establishment of *Opius humilis* and *Diachasma tryoni*. Messrs. D. T. Fullaway and J. C. Bridwell sailed from Honolulu on the second expedition during June, 1914, and arrived at Lagos, Nigeria, on July 24. On August 19 Mr. Fullaway took the parasitized material collected by the expedition at Olokemeji, near Lagos, and sailed for Teneriffe, Canary Islands, where he was able to use *C. capitata* in rearing additional specimens of the parasites emerging from the Nigeria material. With fresh material, Fullaway sailed from Teneriffe September 27 for Hawaii via Havana, Key West, Jacksonville, New Orleans, and San Francisco, arriving at Honolulu on October 27. On arrival he had living material of *Tetrastichus giffardianus*, *Diachasma fullawayi*, *Opius* sp., and *Spalangia* sp.

Mr. Bridwell proceeded from Lagos with an excellent supply of parasitized material, particularly of what appeared to be a new opiine collected at Olokemeji during the period August to October, 1914, to Honolulu via Cape Town and Australia. Unfortunately, he was overtaken before reaching Cape Town with a severe illness which necessitated stops for recuperation in South Africa and Australia of sufficient duration to make it impossible for him to bring living parasites with him to Hawaii.¹

It has already been stated that early in 1914 Mr. D. T. Fullaway introduced at Honolulu a species of dung-fly parasite, *Pachycrepoidius dubius* Ashm. (Pl. XX, fig. 2) which was reared in small numbers by the writers from *C. capitata* pupæ during 1915.

TETRASTICHUS GIFFARDIANUS SILV.

HISTORY.

Tetrastichus giffardianus Silv. was confused with *T. giffardii* Silv., both in the mind of its author and in those of entomologists in Hawaii. The latter species was first reared from *Ceratitis colae* by the entomologist (1912-13) of the agricultural station at Aburi, Gold Coast, Africa. These specimens were identified by Dr. Silvestri as

¹ For full accounts of these parasite expeditions one should consult: Report on an Expedition to Africa in Search of the Natural Enemies of Fruit Flies. F. Silvestri. Bull. 3, Haw. Bd. Agr. and Forestry, Feb., 1914; Report of the Work of the Insectory. D. T. Fullaway. In Rept. Div. Ent. Haw. Bd. Agr. and For., for the biennial period ending Dec. 31, 1914.

new to science. Silvestri reported having reared *giffardii* during the period November, 1912, to February, 1913, from *Ceratitis antistictica* and *C. giffardii* at Olokemeji, Southern Nigeria; from *C. giffardii* at Kotonou, Dahomey, and from *Dacus bipartitus* at Victoria, Kamerun. Silvestri was unable to keep adults alive during the passage from West Africa to Honolulu.

In March, 1915, Silvestri published the description of *T. giffardianus*, stating that previous to then he had confused the species with *giffardii*. *T. giffardianus* was reared by Silvestri from *Ceratitis giffardii* Bezzi, collected at Olokemeji, southern Nigeria, and at Kotonou, Dahomey.

It was *T. giffardianus* Silv. and not *T. giffardii* that was collected by the Fullaway-Bridwell expedition and introduced into Hawaii at Honolulu on October 27, 1914. This fact should be borne in mind, because much of the literature dealing with parasites of *C. capitata* in Hawaii refers to *T. giffardianus* as *T. giffardii*. References to *Tetrastichus* as a parasite of *Ceratitis capitata* in Hawaii should be interpreted to refer only to *T. giffardianus*.

Fullaway introduced into the Hawaiian Islands 300 living specimens of both sexes of *T. giffardianus*. By December 31, or after about two months of breeding in the laboratory, these 300 had increased to 21,431 specimens. Of these, 18,050 were liberated on Oahu, Hawaii, and Kauai by January 1, 1915. Although many thousand specimens have been liberated since December, 1914, none had been recovered as late as February, 1916, from any island except Oahu.¹ In Honolulu specimens have been reared from widely separated points, which would seem to indicate that this parasite has been established successfully. The first recoveries were made by the writers during September, 1915, in Honolulu.

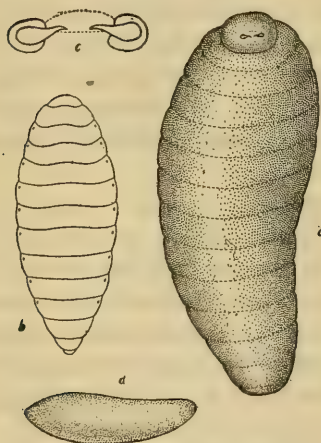


FIG. 17.—*Tetrastichus giffardianus*: a, Ventral view of mature larva; b, dorsal view of same, showing spiracles; c, mouth hooks or mandibles; d, egg. Greatly enlarged. (Original.)

DESCRIPTION.

Adult.—Both sexes of the adult are black with a slightly dark-green iridescence. The antennæ are rather dark, as are also the

¹ Exception: One lot of 46 pupæ of *C. capitata* from coffee cherries collected June 18, 1915, at Kainaliu, Hawaii, showed a parasitism of 63 per cent by *Opius humilis*, 30.4 per cent by *Diachasma tryoni*, and 2.1 per cent by *Tetrastichus giffardii*.



FIG. 1.—*OPIUS HUMILIS*: ADULT FEMALE. GREATLY ENLARGED. (ORIGINAL.)

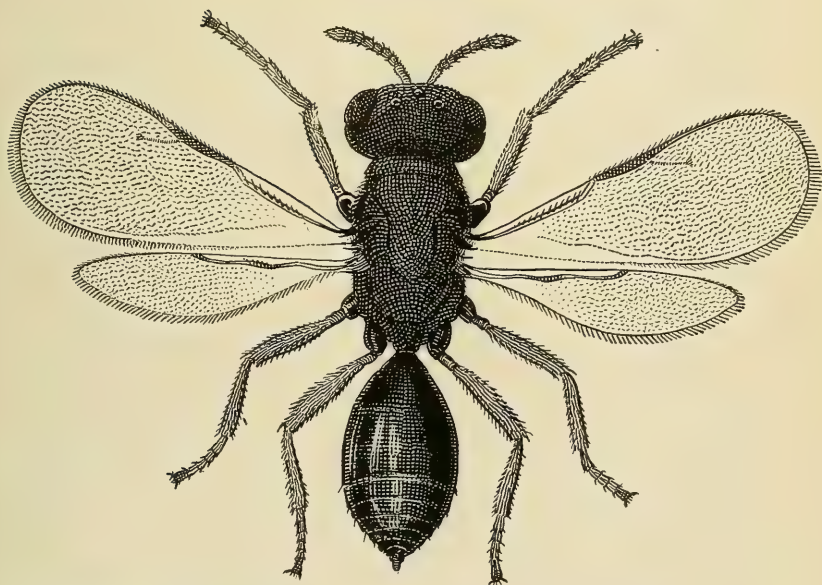


FIG. 2.—*PACHYCREPOIDEUS DUBIUS*: ADULT FEMALE. GREATLY ENLARGED. (ORIGINAL.)

PARASITES OF THE MEDITERRANEAN FRUIT FLY.



FIG. 1.—*DIACHASMA FULLAWAYI*: ADULT FEMALE. GREATLY ENLARGED. (ORIGINAL.)



FIG. 2.—*DIACHASMA TRYONI*: ADULT FEMALE. GREATLY ENLARGED. (ORIGINAL.)
PARASITES OF THE MEDITERRANEAN FRUIT FLY.

femora, but the tibiæ and tarsi are more yellowish. Length of body, about 2 mm. For the original description see Bolletino del Laboratorio di Zoologia, Portici, volume 9, page 374 (1914-15).

Egg.—The egg is pure white, about 0.11 mm. long, and shaped as shown in figure 17, *d*.

Larva.—The well-grown larva is white and grub-like, about 1.8 mm. long (fig. 17, *a*). When viewed from above, spiracles are evident on segments 3-9 (fig. 17, *b*). The mandibles are microscopic (fig. 17, *c*). When first hatched, larvæ are about 0.28 to 0.3 mm. long.

Pupa.—The pupa is about 1.9 mm. long. (See fig. 18.)

BIOLOGY.

Silvestri was unable to keep adults of *giffardii* (or *giffardianus* ?) alive for more than 15 days. His original statement that the female deposits her eggs within the eggs or young larva of the host has been proved by Fullaway and the writers to be incorrect. Oviposition by *T. giffardianus* occurs largely in the well-grown larvæ as in the case of the Opiinae. The adult parasite will enter larval chambers and breaks in the host fruit in search of fruit-fly larvæ as has been proved by the writers under laboratory conditions, and accumulating data seem to indicate that adults oviposit for the most part in larvæ within fruit already fallen to the ground. Adults are capable of beginning oviposition as soon as they emerge from the puparium of the host. The female does not necessarily make a new puncture in the epidermis of its host for each egg deposited; in one instance 41 eggs were deposited through 17 punctures. When the female comes upon a larva within a larval channel, she deposits her eggs at points about its posterior portion, but when access to the larva can be had through a thin membrane of the host fruit, she may deposit her eggs in any portion of the body. The punctures in the epidermis are evident as small dark brown depressions. Of a total of 322 adults reared from 20 pupæ, 194 were females and 128 were males; the number of adults reared from single pupæ varied from 1 to 35.

When the temperature ranges between 66° and 82° F., with a mean of about 74° F., eggs hatch in about 3 days, the larvæ become full grown in about 8 days, and the pupæ yield adults in from 11 to 15 days.

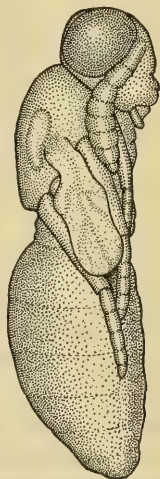


FIG. 18.—*Tetrastichus giffardianus*: Lateral view of pupa. Normal length, 1.9 mm. (Original.)

OPIUS HUMILIS SILV.

HISTORY.

Opius humilis Silv. (Pl. XX, fig. 1) was first reared and described by Silvestri from pupæ of *Ceratitis capitata* collected at Constantia, Cape Colony, Africa, during March, 1913. This parasite does not appear to be an effective factor in the control of *Ceratitis capitata* under South African conditions. Silvestri reared only a few specimens of which he had only 5 representing both sexes in a living condition when he arrived at Honolulu, May 16, 1913. Although after Silvestri

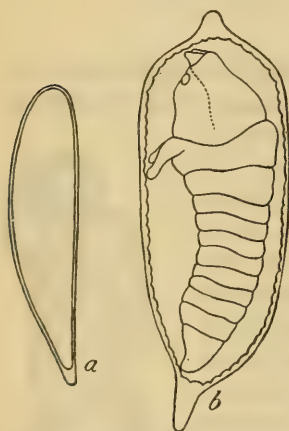


FIG. 19.—*Opius humilis*: a, Egg 1 day old, length 0.45 mm.; b, egg 3 days old, length 0.8 mm. (Original.)

arrived at Honolulu he was able to rear fresh material, the danger that the progeny would be males only was so great that 3 females, with males, were liberated in the coffee fields of Kona, Hawaii, on June 12, 1913. This precaution alone saved the species from extinction in the islands, as the progeny of the specimens kept in the laboratory proved to be males. During October, 1913, large numbers of *Opius humilis* were recovered from *Ceratitis capitata* larvæ in coffee cherries in Kona, Hawaii, and it was found that the species was well established. From the specimens recovered from Kona, colonies were reared and liberated in other parts of the islands. No specimens were liberated in Honolulu until December, 1913. By July, 1914,

humilis was found well established in the city, and by December of that year data already published¹ prove it to have become very abundant and widespread.

DESCRIPTION.

Adult.—The original description of the adult by Silvestri is as follows:

♀ Body ochraceous in color, antennæ brownish-fulvous, wings hyaline with the veins brownish and the central part of the stigma ochraceous-ferruginous, legs with pretarsi brown and the posterior tarsi also in great part brown. Head scarcely more than one-third wider than long, hairy; face with a slight median carina; epistoma slightly elevated; antennæ a little longer than the body, with 35 segments; eyes a little more than twice as long as wide, their lower margin attaining the level of the superior margin of the epistoma. Mesothoracic scutum entire, smooth, with very short parapsidal furrows anteriorly; transverse prescutellar sulcus with eight small

¹ Back, E. A., and Pemberton, C. E. Parasitism among the larvæ of the Mediterranean fruit fly (*C. capitata*) in Hawaii during 1914. Rept. Hawaii Bd. Agr. and For., Dec. 31, 1914.

pits; scutellum smooth with 3 or 4 small pits and a large deep one; metanotum with a short median carina, on the submedian part shortly crenulate before the sublateral pit; propodeum with a median carina, in some specimens divided from the base into two almost contiguous parallel arms posteriorly diverging, the remainder rugose; mesopleuralsulcus foveolate. Wings with venation as shown in figure [Pl. XX, fig. 1.] Abdomen with the first segment rugose on the dorsum, the remainder smooth, with a few hairs; ovipositor almost straight, a little shorter than the abdomen.

Length of body, 2.6 mm.; width of thorax, 0.79 mm.; length of antennæ, 3.3 mm.; length of front wing, 2.6 mm.; width of same, 1.15 mm.; length of third pair legs, 2 mm.; length of ovipositor, 1.15 mm.

Egg.—The egg when first deposited is about 0.45 mm. long, white and of the shape indicated in fig. 19, *a*. As the embryo develops, the entire egg increases in size until when between 2 and 3 days old (Feb., 1916) it becomes about 0.8 mm. long, and over twice as wide as when first deposited, with a protuberance at the anterior end. The developing embryo may be readily seen through the egg membranes (fig. 19, *b*).

Larva.—The white, newly hatched larva is about 1 mm. long. It has a rather large head and 12 distinct body segments. (See fig. 20.) On the anterior ventral portion of the first body segment is a pair of appendages (fig. 20, *b*, *d*), which the larva does not appear to be able to move at will or to use as an aid to

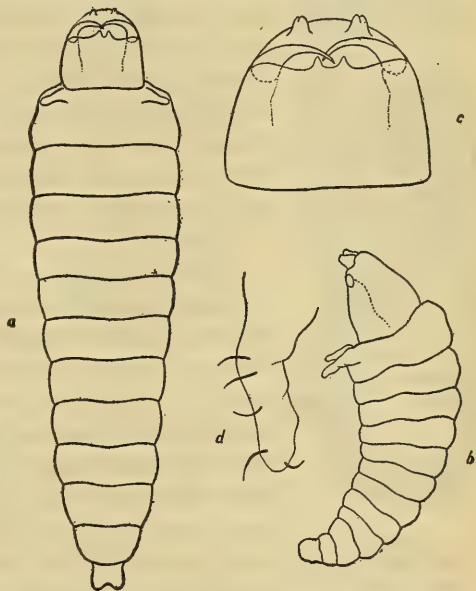


FIG. 20.—*Opus humilis*. Larva: *a*, Ventral, and *b*, lateral view of newly hatched larva; *c*, ventral aspect of head of same; *d*, enlarged thoracic appendage. (Original.)

locomotion. The jaws are very large and strong, being much larger in proportion than in the succeeding instars (fig. 20, *c*). The ventral portion of the head, behind the mandibles, is rather strongly chitinized, forms a support for the latter, and bears on its anterior margin two toothlike projections. On the ventral anterior portion of the head are two fleshy antennal protuberances. The thoracic appendages and large mandibles are lost after the larva molts into the second instar.

Pupa.—The pupa is about 2.3 mm. long (fig. 21). It is very readily distinguished from the other opiine pupæ by the short ovipositor sheath.

DIACHASMA TRYONI CAMERON.

HISTORY.

Diachasma tryoni Cameron (Plate XXI, fig. 2) is primarily a parasite of the Queensland fruit fly (*Bactrocera tryoni*) and was first reared by Brooks and Gurney in New South Wales during 1908, and described as a new species by Cameron in 1911. Of 1,575 pupæ of *Bactrocera tryoni* secured by Gurney from 18 different lots of fruits during the period from January, 1910, to February, 1911, 30.2 per cent were parasitized; the highest percentage of parasitized being 52.2 per cent of 136 pupæ secured at Narara during February, 1910. During April, 1913, at Gosford the parasitism equaled 70 per cent. While *Diachasma tryoni* in Australia attacks principally the Queensland fruit fly, it has been definitely reared there from *Ceratitis capitata* under field conditions, and the indications are strong that it may attack also the island fruit fly, *Trypeta musae* Frogg. It was the opinion of Gurney that this parasite might, upon occasion, become a valuable check upon *C. capitata*.

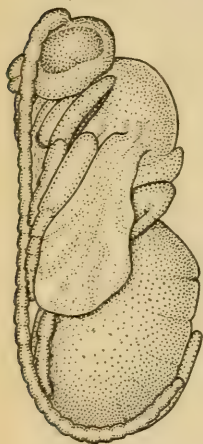


FIG. 21.—*Opius humilis*:
Lateral view of pupa.
Greatly enlarged.
(Original.)

While en route to Honolulu from West Africa, Silvestri, aided by Gurney, secured pupæ of *Dacus tryoni* in New South Wales. From these pupæ Silvestri reared adults of *Diachasma tryoni*, of which he succeeded in introducing at Honolulu 4 female and 3 male specimens on May 16, 1913. Silvestri soon found in his rearing experiments in Honolulu that the progeny were largely of the male sex, hence 4 females, with males, were liberated June 12 in the Kona coffee district of Hawaii, 3 females, with males, on July 4 at Waianae, and 9 females, with males, on July 11 in Kona, Hawaii.

As all the progeny of the remainder of the material held at the insectary were males, the specimens of this parasite now in Hawaii are the progeny of 24 females liberated during June and July, 1913. The first recovery of *Diachasma tryoni* was made by Ehrhorn during August, 1914, from *C. capitata* pupæ from the Kona district of Hawaii. During October, 1914, a systematic collection of infested coffee cherries throughout this district proved *tryoni* to be thoroughly established. Although 3 females were liberated at Waianae, Oahu, on July 4, 1913, no specimens were liberated in and about Honolulu until early in 1915. Yet by October, 1915, this parasite was being reared¹ in small numbers from *C. capitata* pupæ obtained in various parts of the city.

¹ Back, E. A., and Pemberton, C. E., Parasitism among the larvæ of the Mediterranean fruit fly (*C. capitata*) in Hawaii during 1915. Jour. Econ. Ent., v. 9, 1916, p. 306-311.

DESCRIPTION.

Adult.—Silvestri's description of the adult is as follows:

♀. Head, thorax, first segment of the antennæ, front and middle legs testaceous-ferruginous in color; abdomen in great part brown or shining blackish brown; wings slightly infusate, with the stigma and veins brown; third pair of legs entirely brown from apex to trochanters. Head a little broader than the thorax, about one-fourth wider than long with a slight median longitudinal ridge on the face, epistoma slightly semicircularly produced in the middle; antennæ longer than the body, with 45 segments; eyes small, twice as long as wide. Mesothoracic scutum with the parapsidal furrows smooth and deep, convergent, uniting in a deep median pit situated a little before the posterior margin; transverse prescutellar sulcus with a large pit divided into four small ones and each provided also with an incomplete posterior division; scutellum smooth; parascutellar pit with an internal scarcely visible crenulation; metanotum with a short very slight median carina flanked by two small depressions, lateral pit with an abbreviated carina; propodeum with a small anterior conical protuberance directed forward, median and submedian surface almost smooth, a little rugose at the sides and posteriorly, mesoplural sulcus crenulate. Wings with the venation shown in figure [Pl. XXI, fig. 2.] Abdomen with all the segments smooth and shining, with few hairs; ovipositor about as long as the body. Length of body, 3.5-4.5 mm.; width of thorax, 0.95 mm.; length of antennæ, 5 mm.; length of front wing, 4 mm.; width of same, 1.7 mm.; length of third pair of legs, 4.4 mm.; length of ovipositor, 4.5 mm.

♂. Similar to the female.

Larva.—Oval in form, whitish, with the skin smooth and apparently naked, but under strong magnification may be seen to be provided with dense, small, and slender points. Mandibles short, slightly arcuate and gradually attenuate, terminating in a point. Antennæ very short. Length of body, 3 mm.; width, 1.6 mm.

Egg.—The egg of *Diachasma tryoni* is glistening white, about 0.57 mm. long and distinctly attenuated at each end.

Larva.—The newly hatched larva, which is about 1 mm. long, is similar to that of *Opus humilis* (fig. 20, a, b) and *Diachasma fullawayi* in general shape and in the possession of two ventral appendages upon the first body segment. The proportionately large jaws are similar to those of newly hatched larvæ of *humilis* and *fullawayi* but slight distinguishing characters can be found in the large chitinous ventral plate of the head.

Pupa.—The young pupa is white in color, about 4 mm. long, 1.7 mm. wide, and may be distinguished from that of either *humilis* or *fullawayi* by the length of the ovipositor. (Fig. 22.)

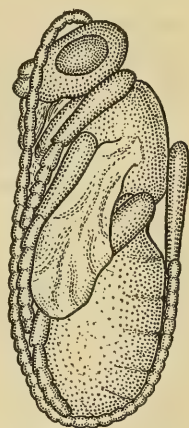


FIG. 22.—*Diachasma tryoni*: Lateral view of pupa. Greatly enlarged. (Original.)

DIACHASMA FULLAWAYI SILV.

HISTORY.

Diachasma fullawayi (Plate XXI, fig. 1) was first reared and described by Silvestri from pupæ formed by larvæ of *Ceratitis giffardi*.

collected in the fruits of *Chrysobalanus* on August 2-3, 1912, at Dakar, Senegal. Silvestri later reared specimens from *C. giffardi* and *C. tritea* at Olokomeji, Southern Nigeria, and from *C. giffardi* at Kokoulima, French Guinea. He was also able to rear this parasite at Dakar from pupæ formed by larvæ of *C. giffardi* parasitized experimentally during the period September 6 to 8, 1912. He was unable, however, to arrive at Honolulu with living specimens and it remained for the Fullaway-Bridwell expedition of 1914 successfully to introduce *D. fullawayi* into Hawaii from Olokomeji via Teneriffe, Habana, and the southern United States. Fullaway arrived at Honolulu on October 27, 1914, with 12 female and 19 male specimens. These had multiplied in the laboratory to 419 females and 1,000 males by December 31, and of this number 35 and 160 specimens were liberated during December at Maunawili, Oahu, and Kona, Hawaii,

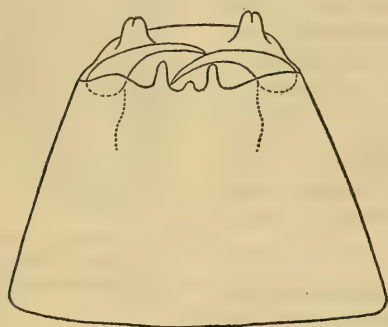


FIG. 23.—*Diachasma fullawayi*: Ventral aspect of head of newly hatched larva; greatest width, 0.3 mm. (Original.)

respectively. Although many specimens have been and are still being reared and liberated, this parasite appears to be well established on the Island of Oahu. In the Kona District of Hawaii, however, where it should have become established with greater ease, only two specimens have been reared from larvæ emerging from coffee cherries. These two specimens of *D. fullawayi* on Hawaii were reared by the writers from larvæ collected at Kainaliu on January 15, 1915, and

February 13, 1916, or about 1 and 13 months, respectively, after the original liberations at this point.¹

On Oahu, particularly in and about Honolulu, this parasite has multiplied with rapidity and was found well established in all parts of the city during September and October, 1915.

DESCRIPTION.

Adult.—The original description of the adult is as follows:

♀. Body ferruginous or ochraceous-ferruginous with the antennæ fulvous brown, the wings hyaline, with the veins fulvous brown and the stigma, in part fulvous-ferruginous, tarsi of the posterior legs slightly brownish. Head somewhat broader than long, densely covered with piliferous points, with the face slightly inflated in the middle to form a carina, antennæ longer than the body, with 44 segments. Eyes small, about twice as long as wide. Mesothoracic scutum with deep converging parapsidal furrows which meet a little before the posterior margin in a deep common pit; from this pit a median furrow proceeds directly forward, at first deep but gradually disappearing on the surface near the middle of the scutum; the entire surface

¹ Examinations made by C. E. Pemberton in Kona during May and June, 1916, found it to be established beyond question.

rather densely and closely hairy; transverse prescutellar sulcus provided with four deep pits, of which the lateral ones are deeper than the median; the scutellum is smooth and rather hairy; slightly crenulate laterally before the prealar pit; metanotum with a small median pit divided by a short carina, crenulate on the sides; propodeum strongly and irregularly foveolate. Front and hind wings with the venation shown in figure [Pl. XXI, fig. 1]. Abdomen with the first segment smooth; ovipositor straight, longer than the abdomen. Length of body, 3.6 mm.; width of thorax, 0.1 mm.; length of antennæ, 5.2 mm.; length of front wing, 3.7 mm.; width of same, 1.37 mm.; length of third pair of legs, 4 mm.; length of ovipositor, 3.5 mm.

♂. Differs from the female in having the wings more or less infusate.

Larva.—The newly hatched larva is similar to that of *Opius humilis*, as illustrated by figure 20, *a*, *b*, as well as that of *Diachasma tryoni*, but it may be readily distinguished from that of *D. tryoni* by the possession of three instead of two toothlike projections on the anterior margin of the ventral chitinized plate of the head (fig. 23).

Pupa.—The pupa, which is about 3.2 mm. long, is most easily recognized from that of *humilis* and *tryoni* by the length of the ovipositor. (Fig. 24.)

BIOLOGY OF THE OPIINE PARASITES.

Very little is known regarding the details of the life history of the three opiine parasites introduced into Hawaii. The biology of parasites now attacking *Ceratitis capitata* in Hawaii is at present being made the subject of special investigation by the junior writer. No data on the length of the various stages have been published except by Silvestri and Gurney. Silvestri's statements may be summarized as follows: That adults of *Opius humilis* emerging on April 3, 1913, were still alive on his arrival at Honolulu on May 16, when they deposited eggs from which adults developed within 14 days; that eggs of *Diachasma fullawayi*, at Dakar, Senegal, deposited on September 6 to 8, 1912, developed adults September 21 to 24, and that *D. tryoni* can complete its egg, larval, and pupal development in from 14 to 16 days. The data supplied by Gurney deal with *D. tryoni* only and will be considered later. The information of the writers is not complete and therefore is given as follows in the form of biological notes in anticipation of a more complete publication. It might be added that such data as are presented here were obtained incidental to other work.

Length of adult life.—Adults die in about 48 hours if not fed. When confined in test tubes $1\frac{1}{4}$ inches in diameter and about 8 inches long and fed daily, they live much longer, as indicated by the data in Table XXIV.

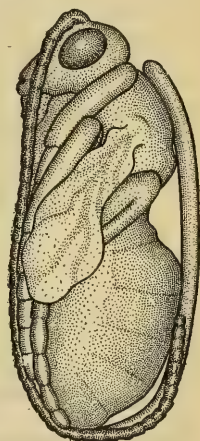


FIG. 24.—*Diachasma, fullawayi*: Lateral view of pupa; normal length, about 4 mm. (Original.)

TABLE XXIV.—*Longevity records of Opius humilis and Diachasma tryoni*¹ at Honolulu from November, 1914, to March, 1915.

Age on date of observation.	Number of specimens dead.				Age on date of observation.	Number of specimens dead.			
	<i>O. humilis.</i>		<i>D. tryoni.</i>			<i>O. humilis.</i>		<i>D. tryoni.</i>	
	♂	♀	♂	♀		♂	♀	♂	♀
24	1	1			67	1	2		
25			1		68	1	1		
26	1		1		69	2	2		
28	3		2		70	1	1		
29	1				71	1	1		
30	3	2			73	2	2		1
32	4	3		1	74	2	3		
34	1				75	1	2		
35	1	3			76		2		
37	2	5	1		79		4		
38	1				80		1		1
43	3	7	2	3	81	1			
45	7	3		1	82	1	3		
46	1		1	4	83		1		
47	2	6	1		84	1	7		
49	3	7			85		1		
50	1	3			87		4		1
51	1	1		1	88	2	3		
52	1	6	1	1	91		2		
53	2	3	1		94	2	2		
54	1	2			95	1	1		
55		1			98		3		
56	2	8		1	100		1		
57				2	101		1		
58	5	8			103		1		
59	1	5			104		2		
60		4			105		2		
62	1	6			107		1		
63		3		1	111		2		
65	3	8		1	124		2		
66		3			125		2		1

¹ No record was kept of adults dying during first 23 days after emergence.

Fourteen females of *Opius humilis* lived to be over 100 days old; the last two being 125 days old. One female *Diachasma tryoni* lived to be 125 days old, although this species appears to be more frail and less able to survive captivity. Unfortunately no record was kept of the number of adults of either species dying during the first 23 days after emergence.

Proportion of sexes.—A count of the sexes of 25 lots of *Opius humilis* reared from *C. capitata* developing in various fruits during September and October, 1914, showed 145 specimens to be females, and 141 males.

Mating.—Mating may occur immediately after emergence in all three species, *Opius humilis*, *Diachasma tryoni*, and *D. fullawayi*. Virgin females may deposit parthenogenetic eggs which, however, develop males only.

Length of life cycle.—There are no satisfactory data on the length of the life cycle under varying climatic conditions. The statement of Silvestri that the egg, larva, and pupa stages may be completed in from 14 to 16 days is a safe estimate for the minimum length required for the development of these stages. Specimens of *O. humilis*, developing from eggs deposited August 21 to 22, 1914,

were already in the pupa stage when examined on August 31, and emerged as adults 13 to 16 days after the eggs were deposited. The temperature during this period ranged between 74° and 85° F., with a mean of about 79° F. In Table XXV are the summaries of emergence from 35 lots of *C. capitata* pupæ secured from various fruits, and these are presented since they demonstrate clearly that which more detailed data will prove further—that *O. humilis* passes through its immature stages more rapidly than either *D. tryoni* or *D. fullawayi*. As the eggs of the parasites are deposited within the well grown larva before it leaves the host fruits, from 1 to 4 days should be added to the duration of the immature stages indicated in Table XXV.

Three *O. humilis* emerged April 3 from *C. capitata* pupæ formed at Honolulu February 2, 1915, placed on Hualalai (temperature range, 31°–70° F.) February 11, taken to Kealahakua March 26, and to Honolulu March 29; i. e., the duration of the immature stages was increased by this combination of cool weather to about 60 days. Many records on file, not included in Table XXV, indicate that detailed data will show more convincingly that *O. humilis* is less affected by cold weather than either *D. tryoni* or *D. fullawayi*.

Dormancy.—There appears to be no tendency for the larvæ of *O. humilis* to pass through a period of dormancy. The larvæ of *D. tryoni* and *D. fullawayi* often apparently suspend activity when they become full grown and remain dormant for several months. Gurney first observed this phenomenon in the development of *tryoni*. *C. capitata* pupæ collected on February 2, 1915, produced adults of *tryoni* normally as indicated by the data in Table XXV, but two individuals emerged on May 5 and 27, respectively, or 92 and 114 days after the pupation of the host. Larvæ of *tryoni* and *fullawayi* in *C. capitata* larvæ in fruits gathered November 27, 1915, were still in the mature larva stage at the end of eight months (July, 1916). Similar data on the duration of other individuals are on file. Mr. J. C. Bridwell has stated to the writers that he has observed this same resting period among the larvæ of an undetermined African opiine, certain adults of which emerged three and four months after the pupation of the host fruit fly.

Instar of larvæ parasitized.—It is generally admitted by those rearing parasites in Hawaii that the adult parasites deposit their eggs, for the most part, in well grown third-instar larvæ while the fruits are still attached to the tree or have fallen to the ground.¹ The data in Table XXVI show a rapid decrease in the percentages of parasitism among larvæ emerging from fruits during each succeeding two or three day interval after the gathering of the host fruit.

¹ A former statement by the writers that the opiines oviposit for the most part in larvæ in fruits still attached to the tree is subject to modification. While oviposition occurs chiefly in coffee cherries attached to the tree, oviposition in kamani nuts occurs largely after the fruits have fallen.

TABLE XXVI.—Percentage of parasitism among larvæ of the Mediterranean fruit fly emerging during various periods after the gathering of the host fruit (coffee).

Locality.	Date of collection of fruit.	Date of larval emergence.	Number of pupæ yielding adults or parasites.	Percentage of parasitism.			
				<i>Opius humilis</i> .	<i>Dia-chasma tryoni</i> .	<i>Dia-chasma fullawayi</i> .	Total.
1752 Luso Street, Honolulu.	Oct. 21,—	Oct. 21-23..	37	78.4	0	16.2	94.6
		Oct. 23-25..	34	64.7	0	15	79.7
		Oct. 25-27..	52	20.0	0	5.4	25.4
Booth Estate, Pauoa Valley.	Dec. 8, 1915	Dec. 8-10...	256	0	0.4	92.1	92.5
		Dec. 10-13..	338	0.3	.6	78.1	79
		Dec. 13-16..	609	.6	.1	43.8	44.5
		Dec. 16-18..	258	0	0	12.8	12.8
		Dec. 18-20..	76	0	0	6.6	6.6
Kealakekua, Kona district.	Dec. 1, 1915	Dec. 1-2....	5	40	60	0	100
		Dec. 2-3....	15	86.7	13.3	0	100
		Dec. 3-4....	21	71.4	23.8	0	95.2
		Dec. 4-5....	33	66.6	21.2	0	87.8
		Dec. 5-6....	46	54.3	13	0	67.3
Kainaliu, Kona district...	June 18, 1915	June 18-19..	46	63	30.4	0	93.4
		June 19-20..	65	50.7	41.5	0	92.2
		June 20-21..	107	56	32.7	0	88.7
Kahaloa, Kona district...	Oct. 30, 1914	Oct. 30-Nov. 3..	41	80.4	2.2	0	82.6
		Nov. 3-6....	240	23.3	0.4	0	23.7
		Nov. 6-9....	125	3.7	0	0	3.7
		Nov. 9-11..	64	0	0	0	0
Hookena, Kona district...	Oct. 31, 1914	Oct. 31-Nov. 3..	52	16.7	40.7	0	57.4
		Nov. 3-6....	36	17	19	0	36
		Nov. 6-9....	86	1.2	0	0	1.2
		Nov. 9-11..	79	0	0	0	0

Resistance to cold-storage temperatures.—Indications are that *Opius humilis* can withstand greater cold for longer periods than can its host. Thus 5 *O. humilis* emerged from 2,500 *C. capitata* pupæ after they had been refrigerated for 9 days at about 26° F. Four lots of 1,200 pupæ refrigerated at the same temperature for 5, 6, 7, and 8 days yielded on removal to normal temperatures 30, 32, 8, and 4 *Opius*. No adult *C. capitata* emerged from those pupæ refrigerated from 5 to 9 days, but from 1,300 pupæ, refrigerated at about 26° F. for a period of 4 days, 3 adults emerged along with 40 *O. humilis*.

No adult *C. capitata* emerged from two lots of 1,900 and 4,500 pupæ refrigerated for 9 and 10 days, respectively, at 32° F., but 7 and 13, respectively, of *O. humilis* emerged. From 1,228 pupæ refrigerated for 18 days at 34° to 36° F. there emerged no adult *C. capitata* but 2 *O. humilis*.

REARING PARASITES.

In rearing parasites the writers have followed, in the main, the methods employed by the Hawaiian Board of Agriculture and Forestry as developed by Messrs. Silvestri, Fullaway, and Bridwell. The board failed to rear the opiine parasites successfully until Mr. J. C. Bridwell, then assistant superintendent of entomology, altered

the procedure so that the parasites were given an opportunity to oviposit in the larvæ within host fruits under more normal conditions. The methods previously used permitted much moisture to gather on the sides of the glass jars in which the host fruits and parasites were placed. The method now recommended by Mr. Bridwell consists in the use of two ordinary nursery flats, the boxes being 16 by 12 by 3 inches. Into one of these is placed a layer of dry sand and a wire container so arranged that it will hold the infested host fruits exposed within it clear of the sand. The second tray, the bottom of which has been replaced by fine-mesh copper wire, is used as a cover and is made sufficiently small so that it can be inverted and thrust down into the tray containing the sand and fruits as soon as vials containing the adult parasites have been unstoppered and placed upon the fruits. By pressing the edges of the covering tray well into the sand the adult parasites are prevented from escaping and ants are, temporarily at least, prevented from interfering with the experiment. When the covering tray is in place, the wire-screen top is not far from the exposed fruits; hence the parasites are forced to confine their activities where they net the best results. The Bridwell method has not only made it possible to rear large numbers of opiines quickly and without skilled labor but is largely responsible for the success of the Fullaway-Bridwell parasite expedition to Africa.

The writers have been able to rear both sexes of the opine parasites in large numbers very easily since the summer of 1914 by merely placing in test tubes about 2 inches in diameter a number of infested host fruits and parasites. This method requires greater care and produces much sweating of the sides of the containers, but parasitic material of both sexes can be very quickly secured for experimental work, and the investigator has the advantage of being able to observe the activities of the adult parasites. The objectionable feature of excessive moisture was overcome by the use, in the summer of 1914, of a wooden box, the top and bottom of which was of fine-mesh copper wire which contained a sliding shelf made of coarse-mesh wire supported midway between the top and bottom of the box and which could be easily removed through one end of the box which was hinged. This device possessed the advantage, demonstrated by Bridwell, in that it prevented accumulations of excessive moisture and confined the parasites closely to their hosts, but was not so well adapted to the purposes of parasite work since the host larvæ which pupated on the bottom of the box could not be so readily secured. After the host larvæ have emerged from the exposed fruits the pupæ may be easily sifted from the sand beneath the fruits and held in glass jars until the adult parasites have emerged.

It was not necessary to expose adult opine parasites to strong sunlight for a few minutes each day to hasten mating, as recommended

by Bridwell, and both sexes were obtained within the laboratory without this precaution, possibly owing to the fact that the laboratories were remarkably well lighted.

Cannibalism.—Although thousands of adults representing all three of these opiine parasites have been reared during the past two years, not more than a single individual has been reared from one fruit-fly puparium. Larvæ of the Mediterranean fruit fly within coffee cherries which had been exposed to the attack of *Diachasma fullawayi* during January, 1916, were found to have been attacked in several places, and examination made of the body contents of the parasitized fruit-fly larvæ proved that as many as 8 eggs had been deposited in certain instances. It seems very probable, therefore, that in the field, under normal conditions, adult parasites do not discriminate against larvæ already parasitized when seeking a host and that due to an excessive number of parasitic larvæ within a single host a certain amount of cannibalism occurs. Cannibalism among opiine parasites was first observed by the senior writer while examining the body contents of larvæ parasitized by *Diachasma fullawayi* as previously mentioned. A newly hatched larva was observed vigorously and effectively to attack a second larva of the first instar with its large mandibles. Later examination of large numbers of fruit-fly larvæ by the junior writer have proved conclusively (1) that the last opiine parasite to hatch within a host first kills all other parasitic larvæ within the same host; (2) that the newly hatched larva is more capable of vigorous attack than one which has become engorged; and (3) that it may attack not only larvæ of another species but those of its own as well. As many as eight dead and one living first-instar larvæ have been found in a single host.

STRUGGLE FOR SUPREMACY AMONG PARASITES.

The parasites of *Ceratitis capitata* have been introduced too recently into Hawaii to warrant conclusive statements regarding the outcome of the struggle for supremacy which is clearly taking place. *Opius humilis* has an advantage among the opiines of being more hardy and of being able to pass through the immature stages more rapidly, and it is somewhat less affected by cool weather, whereas *Diachasma tryoni* and *D. fullawayi* have the advantage of possessing much longer ovipositors and are consequently better equipped to reach their host larvæ through the tissues of infested fruits. The more rapid development of the egg and larva stages of *Opius humilis* is, however, not in its favor when it is forced to compete within the same host with either *Diachasma tryoni* or *D. fullawayi*, owing to the cannibalistic habits of the newly hatched opiine larva, which impel it to seek out and destroy larvæ that have hatched earlier and already commenced feeding within the same host.

While it will probably take a number of years to determine just what advantage the longer ovipositor will afford *Diachasma tryoni* and *D. fullawayi* over *Opius humilis*, the data in Table XXVII clearly demonstrate the value of the cannibalistic habits of the newly hatched larva to the more slowly developing species.

TABLE XXVII.—Percentage of parasitism by *Opius humilis* and *Diachasma tryoni* in larvæ of *Ceratitis capitata* in Kona, Hawaii.

Locality.	Dates of larval emergence, 1915.	Percentage of parasitism.			Locality.	Dates of larval emergence, 1915.	Percentage of parasitism.		
		<i>Opius humilis</i> .	<i>Diachasma tryoni</i> .	Total.			<i>Opius humilis</i> .	<i>Diachasma tryoni</i> .	Total.
Kainaliu.....	Jan. 15-16	97.6	0.8	98.4	Honaunau...	Mar. 24-26	81.2	0	81.2
	Jan. 16-18	92.7	.8	93.5		June 17-18	46.7	40.3	87.0
	Feb. 6-8	85.3	9.3	94.6		June 19-20	40	49.6	89.6
	Mar. 15-18	92	0	92.0		Sept. 19-20	13.9	65.1	79.0
	Mar. 18-19	85.1	0	85.1		Sept. 20-21	10.6	69.6	80.2
	June 18-19	63	30.4	93.4	Kealakekua..	Feb. 6-8	79	0	79
	June 19-20	50.7	41.5	92.2		June 16-18	31.4	23.9	55.3
	June 20-21	56	32.7	88.7		Sept. 13-19	17.6	67.6	85.2
	Jan. 19-20	82.8	3.4	86.2		Sept. 19-20	23	56.4	79.4
	Feb. 9-10	64.2	4.7	68.9		Sept. 20-21	37.3	48.3	85.6
	Mar. 19-24	73.9	.6	74.5					
Honaunau...									

Data previously published by the writers have shown that *O. humilis* itself is capable of killing as high as 80 to 100 per cent of the larvæ of *Ceratitis capitata* developing in coffee cherries in the Kona district of Hawaii. The data secured during 1915 showed that there was a decided increase in the percentage of parasitism caused by *D. tryoni*. This increase, however, as shown by the data of Table XXVII, was largely at the expense of *O. humilis*, since the total percentage of parasitism was not in excess of that which *O. humilis* could have brought about by its own efforts. In the absence of large amounts of data necessary to the definite establishment of this point, the writers are of the opinion that similar fluctuations in the relative importance of *humilis* and *tryoni* are likely to occur each year unless *fullawayi* becomes thoroughly established, in which case it is likely to supplant *tryoni*. The gradual increase in the abundance of *tryoni* during the year is accounted for by the gradual removal, as the summer months approach, of the restrictions upon parasite development which cause a greater relative acceleration in the development of *tryoni* than in the case of *humilis*. This, aided by cannibalism, explains the ascendancy of *tryoni* during the summer and of *humilis* during the colder winter months. It would appear that *C. capitata* in the coffee sections of Hawaii would have been quite as effectively controlled had no opiine other than *humilis* been introduced.

It is doubtful if the same fluctuation in the relative abundance of *tryoni* and *fullawayi* on the one hand and of *humilis* on the other

will take place in the warmer littoral regions about Honolulu where checks due to cool weather are not so effective as in Kona. A study of the data in Table XXVIII shows that *Diachasma fullawayi* gives promise of being a most efficient parasite, particularly of fruit-fly larvæ in coffee cherries, since almost unaided it produced a mortality, in one instance, of 92.5 per cent of 256 larvæ emerging from coffee cherries in Honolulu on December 8 to 10, 1915, which date was about one year after it had been liberated.

Data more recently secured by the junior writer indicate that instead of supplementing the work of the opiines, *Tetrastichus giffardianus* will prove a competitor, as its larvæ appear to be able to hold their own against opiine larvæ within the same host, usually causing their death. While both *Tetrastichus giffardianus* and *Pachycrepoideus dubius* (Pl. XX, fig. 2) have been reared during 1915 and 1916, neither is sufficiently abundant to become an effective factor in control at present.

GENERAL EFFECTIVENESS OF PARASITE CONTROL.

Only a beginning has been made in determining the effectiveness of parasites as a control factor in the Hawaiian Islands, yet the rapidity of establishment and increase of the parasites has been very gratifying. The data already published recording the percentage of parasitism secured during 1914 and 1915, together with the additional data of Table XXVIII, indicate, however, that while parasitism in such fruits as the coffee cherry is remarkably high, in fruits with a thicker pulp, such as the orange, it is very low. The data of Table XXVIII have been chosen particularly as they demonstrate that immense numbers of adult *Ceratitis capitata* are developed in spite of the excellent work of the parasites in certain host fruits. Since adult fruit flies can live many months and oviposit quite regularly as shown by the biological data, they have been able, with the aid of the unprecedented variety and abundance of host fruits growing in Hawaii, thus far to keep such an ascendancy over their parasites that they cause the infestation of practically all fruits which are permitted to ripen. It would appear that unless effective pupal or egg parasites are introduced, or unless care is given to the elimination of host fruits which more thoroughly protect the larvæ from parasite attack and to the planting of fruits in which the fly is heavily parasitized, little of practical value can be expected from the parasites discussed in this paper either in rendering host fruits entirely free from attack or in raising the present quarantine against Hawaiian fruits. In Kona, Hawaii, where the percentage of parasites in coffee cherries has been phenomenally high for two years, it has been high enough merely to render an occasional fruit free from attack.¹ The control

¹ The statement of W. M. Giffard that the infestation of coffee cherries during 1914 was at least 50 per cent less than during the previous year, and that in some fields it was difficult to find any great infestation, should be interpreted as referring to the cherries which, although nearly all infested, were infested so late in development that their pulp was little affected when the fruits were picked.

executed by parasites has, however, effected a benefit to coffee growers which has probably already repaid the Territory of Hawaii for all money expended in parasite introduction, since the parasites, by greatly reducing the abundance of adult flies, have postponed the infestation of the pulp until the cherries have become quite well ripened, at which stage little loss to the coffee results.¹

TABLE XXVIII.—Percentage of parasitism among larvæ of the Mediterranean fruit fly developing in host fruits during November, 1915–February, 1916.²

Locality.	Host fruit.	Date of larval emergence.	Total number pupæ yielding adults or parasites.	Percentage of parasitism.				
				Opilus humilis.	Diachasma tryoni.	Diachasma fullawayi.	Tetrastichus: giffardianus.	Total.
Hilo, Hawaii:								
Pitman Street.....	Coffee.....	Nov. 18–22, 1915..	11	0.0	0.0	45.4	.....	45.4
Do.....	Wing kamani.....	Nov. 20–25, 1915..	16	18.8	0	0	0	18.8
Hilo Hotel.....	Coffee.....	Nov. 19–22, 1915..	5	0	0	60	0	60.0
Five Miles.....	do.....	Nov. 18–22, 1915..	49	12.2	0	0.0	0	12.2
Boarding School.....	do.....	Nov. 20–29, 1915..	90	1.1	0	2.2	0	3.3
Kona, Hawaii:								
Kealahkekua.....	do.....	Dec. 1–5, 1915.....	77	71.4	22.1	0	0	93.5
Kainaliu.....	do.....	Dec. 3–4, 1915.....	64	68.7	28.1	0	0	96.8
Honaunau.....	do.....	Dec. 4–6, 1915.....	119	63.9	28.9	0	0	92.8
Honolulu:								
1560 Beretania Street.....	Loquat.....	Dec. 15–20, 1915..	6	16.6	0	0	0	16.6
Do.....	do.....	Dec. 21–24, 1915..	10	40	0	0	0	40
Do.....	do.....	Jan. 3–7, 1916.....	40	5	5	5	0	15
Waikiki.....	Ball kamani.....	Dec. 20–27, 1915..	302	0	0	0	0	0
Ohua Lane.....	do.....	Dec. 22–31, 1915..	75	0	0	0	0	0
Ainahau.....	do.....	Dec. 29, Jan. 1, 1916	186	0	0	0	.5	.5
Ohua Lane.....	do.....	Jan. 4–14, 1916.....	430	.5	0	.2	.3	1.0
Queens Hospital.....	C. oliviforme.....	Jan. 25, Feb. 2, 1916	297	2.6	2.0	2.6	0	7.2
Do.....	do.....	Jan. 27, Feb. 4, 1916	818	3.6	.6	.7	0	4.9
Do.....	do.....	Jan. 29, Feb. 9, 1916	1,954	2.4	.2	.5	0	3.1
Do.....	do.....	Feb. 4–18, 1916.....	870	1.4	0	.5	0	1.9
Do.....	M. elengi.....	Jan. 29–Feb. 9, 1916	1,543	.3	0	.1	0	.4
Do.....	do.....	Feb. 4–18, 1916.....	1,194	.5	0	0	0	1.5
Do.....	do.....	Feb. 7–18, 1916.....	1,998	.1	0	0	0	.1
1814 Ahuula Street.....	Bunchosia.....	Nov. 24–29, 1915..	45	31.1	0	0	0	31.1
Punahou Street.....	Chinese orange.....	Jan. 1–10, 1916.....	321	.6	.3	.3	0	1.2
Wildner and Thurston Streets.....	do.....	Dec. 17–22, 1915..	14	21.4	0	7.2	0	28.6
Do.....	do.....	Dec. 22–31, 1915..	286	2.1	0	0	0	2.1
Wildner and Pensacola Streets.....	do.....	Dec. 22–27, 1915..	45	15.5	0	0	0	15.5
Upper Pauoa Valley.....	do.....	Jan. 17–20, 1916.....	162	11.7	5.6	0	0	17.3
Wildner and Keeamaku Streets.....	do.....	Jan. 20–24, 1916.....	817	1.2	.7	0	0	1.9
St. Mary Mission.....	do.....	Dec. 17–20, 1915..	143	7	0	0	0	7
1436 Young Street.....	do.....	Dec. 16–24, 1915..	316	1.5	0	.3	0	1.8
Enos Lane.....	do.....	Dec. 13–16, 1915..	5	40	0	0	0	40
Makiki and Lunalilo Streets.....	do.....	Dec. 9–20, 1915.....	182	3.9	0	5.5	0	9.4
Do.....	do.....	Dec. 8–13, 1915.....	59	0	0	3.4	1.7	5.1
Lunalilo Home.....	do.....	Nov. 26–29, 1915..	4	50	0	25	0	75
Do.....	do.....	Nov. 29, Dec. 1, 1915.	43	14	0	7	0	21
1571 Makiki Street.....	Coffee.....	Dec. 1–6, 1915.....	292	.7	.3	0	0	1.0
Do.....	do.....	Nov. 29, Dec. 1, 1915.	54	5.5	0	85.2	0	90.7
1752 Luso Street.....	do.....	Dec. 8–13, 1915.....	415	1.7	.5	77.3	0	79.5
Booth, Pauoa Valley.....	do.....	Dec. 8–10, 1915.....	256	0	.4	92.1	0	92.5
Do.....	do.....	Dec. 13–16, 1915.....	611	.6	.1	43.7	.3	44.7
Upper Manoa Valley.....	do.....	Dec. 9–13, 1915.....	12	0	0	83.3	0	83.3
2030 Nuuanu Street.....	do.....	Dec. 11–13, 1915.....	22	4.6	0	81.8	0	86.4
Pauoa Valley.....	do.....	Jan. 1–3, 1916.....	9	11.1	0	88.9	0	100.0

¹ The losses to coffee growers due to excessive fruit-fly attack have been discussed on p. 34.

² Braces are used only when denoting the same lot of fruit.

While it seems evident that the favored host fruits of *C. capitata* will always be well infested if present cultural conditions persist, it is hoped that the value of the parasites may be sufficiently enhanced to free from attack such fruits as the avocado pear, which at present is infested just at the stage at which it becomes fit for harvesting.

The general effectiveness of parasite control will be increased with the discovery and introduction of a suitable egg parasite.

ARTIFICIAL CONTROL.

The only method employed at the present time in Hawaii satisfactorily to protect fruits from attack of the Mediterranean fruit fly is the covering of the fruits while they are still too green to be affected. The value of the use of cold storage as a method of rendering fruits already harvested free from danger as carriers of the pest has been demonstrated, but cold storage, of course, can have no bearing on the activities of the fruit fly in the orchard. No satisfactory substance has yet been discovered for trapping adult females, and the killing of adults of both sexes by poison sprays is not a feasible method of control in Hawaii under present cultural conditions any more than is the destruction of the immature stages by the burial, submergence, burning, or boiling of the infested host fruits. The exceptional conditions found in Hawaii make impracticable at the present time the application of any of these field methods of control, except that of covering the young fruit, notwithstanding the fact that the value of these control measures when they can be consistently, intelligently, and universally applied, has been demonstrated.

PROTECTIVE COVERINGS.

The only certain method now known of protecting fruits from attack by the Mediterranean fruit fly is to cover them when still quite young with some type of covering through which the female will not deposit eggs. During 1898 Fuller reports that about 22,000 running yards of mosquito netting were imported into South Africa for use in covering trees to protect the fruit from fruit-fly attack. The cloth was sewed into bags sufficiently large to be slipped over the trees and tied about the trunk. This method has been employed by the writers in protecting ripening peaches. Care must be taken, in Hawaii at least, to place the bags over the trees when the fruits are very small or early infestations will have already occurred which, after the coverings have been placed, will produce generations of adults that will result in the infestation of the entire crop beneath the covering.

Covering the entire tree is too expensive to be followed out on a large scale, and entirely impractical with large trees or in windy areas. Protecting fruits with individual coverings made of cloth or paper is more popular in Hawaii. Fruits inclosed in paper bags are well

and cheaply protected. Coverings of cheese-cloth are often matted against the fruit by rains, thus making it possible for the female fly to oviposit in the fruit. The practice of covering mangoes with paper bags will afford protection to certain scale insects and permit them to develop and ruin the fruit.

Frequently all the fruits on a tree may be seen inclosed in paper bags. While this method of covering each fruit gives protection from the fruit fly, it involves much labor and patience and its practicability can only be determined by the value placed upon the fruit by the owner. So severe is fruit-fly attack in Hawaii that this method, in some one of its many modified forms, is the only remedy if fruits are to be brought to maturity uninfested.

CLEAN CULTURE.

Clean culture in its broadest sense includes not only the detection, collection, and destruction of all infested fruits but also the elimination of useless or unnecessary host trees or shrubs. In some one or all of its phases it has been recommended and practiced in every country where the fruit fly is a pest, and in each one of these countries the lethargy displayed by a majority of the people, no matter how much they have regretted their losses, has rendered the clean cultural methods inefficient. The effectiveness of clean culture depends upon many factors, of which cooperation among property owners, honesty on the part of inspectors, climatic and host relationships, the topography of the country, and a thorough knowledge of host fruits on the part of the director are the most important. Clean culture in the Bermudas, where conditions are exceptionally favorable for stamping out the pest, was rendered less effective, up to 1914, because there was lacking a thorough knowledge of the complete list of host fruits subject to infestation. The fruit fly has been stamped out at Blenheim, Napiers, and Davenport, New Zealand, and at Launceston, Tasmania, by the application of such clean cultural methods as the destruction of the fruits and the treatment of the soil beneath the trees with kerosene immediately after the discovery of the pest. The only other recorded instance of success attained as a direct result of clean cultural methods is that of the orange growers of the Blackall Range, in Queensland, Australia. These growers held a council and voted to grub out every kind of fruit tree except the orange, which was their staple crop. As a result of this drastic remedy the fly had nothing in which to breed during nine months of the year in this section, and therefore ceased to be a pest.

The clean-culture campaign instituted by the Hawaiian Board of Agriculture during the fall of 1911 and continued by the Federal Bureau of Entomology from October, 1912, until April, 1914, was unsuccessful from its inception, since it did not protect the fruit

from attack. The main factors contributing to failure were lack of adequate police powers, adverse host and climatic conditions, and the absence, at that time, of any commercially grown orchard crop worth protecting. The impracticability of control by the clean-culture method was recognized by Mr. C. L. Marlatt, who, as a Federal representative immediately in charge of the Hawaiian investigations, was in personal touch with the problem during September, 1912. It was felt, however, that inadequate as this method had proved itself after a nine months' trial from the standpoint of alleviating the Hawaiian situation, it seemed still to offer the best-known way of safeguarding the interests of mainland fruit growers. Therefore, for the purpose of lessening the opportunities of spread to the coast, the destruction of fruits which could be carried on board ships was continued. It was not until after representatives of California,¹ Hawaii,² and the Federal bureau had reached the conclusion that no benefit was accruing either to the local or to the mainland interests that the campaign was discontinued.

It is doubtful if ever a clean-culture campaign against the Mediterranean fruit fly was organized so efficiently or on so large a scale as that organized by Mr. W. M. Giffard of the Hawaiian Board, to include the city of Honolulu. That this method should prove a failure under Hawaiian conditions is no reflection upon the ability of those in charge of the work. Inspectors were prohibited from gathering and destroying fruits unless they could first prove to the satisfaction of the property holder that each fruit was infested, and this restriction upon the activities of the inspectors naturally led to numerous difficulties, particularly with the poorer and uneducated classes who often exerted every effort to save their fruit. This restriction also prevented a systematic gathering of all host fruits within a given area, but necessitated many examinations for the removal, on ripening, of the fruits of each individual tree. As fruits ripen rapidly in the semi-tropics, it proved a physical impossibility to arrange visits by the inspectors frequently enough to prevent infested fruits from falling to the ground.

The data of Tables III to V illustrate the immense number of host trees and shrubs available for infestation in Honolulu, and the ease with which the fruit fly, uncurbed by climatic conditions, may find fruit for oviposition during any day of the year. A glance at Plates IV, VI, XII, and XIX will convince one of the absurdity of endeavoring to remove all the fruits from many of the huge host trees of the islands. The writers know of many winged kamani trees, beneath which infested nuts may be gathered each week of the year, so tall

¹ Report of Investigation of the Fruit-fly situation in the Territory of Hawaii, F. Maskew. Monthly Bul. Cal. St. Com. Hort., v. 3, 1914, p. 227-238.

² W. M. Giffard, Letter of Transmittal to Bulletin No. 3, Haw. Bd. Agr. and For., 1914, p. 7.

and brittle that to remove the fruits before they ripen would be impossible. To this example might be added many others in which the removal of ripening fruit would be equally impracticable.

That the campaign was successful in eliminating the bulk of the fruit ripening in Honolulu during the greater part of the year is evidenced by the inability of the Hawaiian Board to obtain any large amount for their experimental work with parasites during the period the campaign was in progress. Excepting May, June, and early July, it was not an impossibility to gather the bulk of fruits ripening in Honolulu, but during these three months tons of ripening mangoes, falling continuously, presented a situation that could not be successfully combated. (See Pls. XII and XIII.) While tons of mangoes were carried daily to the incinerator or the city dumps, except from the standpoint of city sanitation nothing of value was accomplished.

Notwithstanding the fact that the bulk of the ripening and infested fruits were collected and fruit-fly conditions were unquestionably improved from the standpoint of the numerical abundance of adult flies, the important fact remains that the number of fruit flies that succeeded in reaching maturity was sufficiently large to infest practically every fruit ripening within the city. Kerosene traps placed throughout one of the cleanest sections of the city captured large numbers of flies as proved by recorded data on file both with the Hawaiian Board and this bureau. (See Table XXI, p. 76.)

So far as the writers know, there is no way in which clean culture can be made effective in Hawaii under present conditions. There are no impelling incentives. The islands are thoroughly overrun with the fruit fly, and this applies quite as much to the guava scrubs in pastures (Pl. II), on lava flows, and in mountain valleys and ravines as within the city limits. By far the larger proportion of host trees and shrubs are grown more for protection from the semitropic heat and for their ornamental value than for their fruits (Pl. VI). Large numbers of the host fruits are not edible. The destruction of host vegetation is out of the question until it can be proved that some advantage worth while can be gained. To cut down all host trees of Honolulu at the present time would be to remove a large percentage of her prized vegetation without giving her citizens adequate compensation.

ELIMINATION OF HOST TREES.

It has been stated under a discussion of clean-culture methods that the elimination of host trees and shrubs in Hawaii is impracticable at the present time. Should the Mediterranean fruit fly ever become established in California or the Southern States, wherein there is no such wealth of host fruits and where climatic conditions would assist in control, the elimination of host trees other than the orchard cultures to be protected would play a most valuable part in control

measures. Dr. Trabut found that in Algeria the infestation of oranges greatly increased after the introduction of such crops as peaches and persimmons, since these fruits furnished food for the fly during the summer and early fall months, which for the fruit fly had been starvation months previous to the cultivation of these fruits. Aided by these introduced summer crops, the fruit fly was able greatly to increase, so that when the orange crop began to ripen during the fall and winter months, the pest could attack it with increased force. The elimination of a comparatively few host trees, numerically speaking, in Bermuda would mean the elimination of breeding places over considerable areas. The destruction of unnecessary and valueless host trees serves to restrict the breeding ground, as well as to destroy the sequence of ripening hosts so that many adult flies will die while attempting to bridge the ensuing starvation periods, during which no host fruits can be found for oviposition.

SPRAYING.

It has been demonstrated that the Mediterranean fruit fly must feed for about four days after emergence in the warmer months before the females are capable of ovipositing in fruits. This feeding period may be extended to 10 days during winter in littoral Hawaii. Although the interval between emergence and oviposition is short, it offers the best opportunity to kill this pest by means of poisoned baits or sprays. Mally, in South Africa, first appreciated the vulnerability of this point in the life cycle and developed and demonstrated the value of poison sprays as a factor in the control of the Mediterranean fruit fly. Berlese, in Italy, however, working quite as independently, carried out similar experiments to check the olive fly (*Dacus oleae*). Equal credit is due Mally and Berlese for the use of poison sprays in combating fruit flies.

The results of the experimental work of Mally during 1904-5 and of Dewar during 1915 were not successful, although encouraging. The later work of Mally during 1908-9 proved conclusively the value of poison sprays under South African conditions. Mally states that "a severe outbreak of the pest in a commercial peach orchard was brought to a sudden and practically complete halt, and the fruit maturing later was marked under the guarantee of freedom from maggots," while the infestation among fruits on check trees increased until practically all fruits had become infested. These experiments lead Mally to state that *Ceratitis capitata* can be controlled most perfectly under orchard conditions by means of a light sprinkling of a poisoned sweet over the trees just before or during the ripening period of the fruit. In 1912 Lounsbury demonstrated the applicability of the poison spray under town conditions in South Africa during most unfavorable weather conditions, and concluded that if spray-

ing is properly done this remedy is applicable under town conditions, even where the summer rainfall may be heavy.

In Western Australia Newman carried on spraying experiments during a 5½-months period (December 5, 1913, to May 25, 1914) when the fruit fly was most destructive. From the orchard at Crawly Park, in which he experimented, little or no sound fruit, other than grapes, had been picked for several years. The extreme dryness of the Western Australia summer, during which little or no rain or dew falls, affords an especially opportune time for making the best use of poison sprays. Newman estimated the cost of spraying an acre, where an application of one pint of spray was made every 12 to 14 days, to be from \$1.50 to \$2 per fortnight, and stated that this sum was a mere bagatelle to the loss of fruit during a similar period over a like area. His work convinced Newman that good results will follow the consistent application of poison sprays, particularly when supplemented by the proper destruction of infested fruits.

In the Hawaiian Islands there are no real orchards in which spraying experiments can be conducted under commercial conditions. Severin states that while he captured in 10 kerosene traps, hung among 400 trees, 10,239 flies during a 5-weeks period before starting spraying work, in the following 5 weeks, during which these trees were sprayed about once a week, the same traps caught only 182 flies, and of these 93 were caught during the first 6 days after the first application of spray. Inasmuch as the orchard in question is composed of small citrus trees interplanted with peach and contains a few strawberry-guava, fig, Chinese-orange and rose-apple trees, and is surrounded on one side by wild guava scrub, it is unfortunate that no data were given on the time of the year the spraying was done or on the condition of the host fruits in and about so small an orchard.

The conclusions of Weinland following his spraying experiments conducted during 1912 in dooryards of Honolulu are misleading. He used the data from 7 traps as a basis for his favorable report; had he used the data from 10 other traps in the same series of his experiments which are on file with the Hawaiian Board of Agriculture and Forestry he could have shown that on the whole his experiments were not successful, and that in several instances he caught more flies after spraying than before. The writers have demonstrated from an immense amount of data on the number of flies caught in single traps throughout a given year that even when no spraying is done there may be a sufficient falling off in the numbers of fruit flies captured to mislead one into thinking that the trees had been sprayed.

The only test of poison sprays made by the writers was in an attempt to control the Mediterranean fruit fly under adverse town conditions such as have been described on page 11. The city block in Honolulu bounded by Punahou, Beretania, Wilder, and Makiki Streets was sprayed every 2 or 3 days from July 17 to August 28, 1913. The adjoining blocks to the southeast were held as a check and the number of flies captured in 145 traps in the sprayed area and in 147 traps in the check area constituted the basis for determining the benefits of the poison spray. Knapsack sprayers only were used, and while all trees and shrubs received spray, none were sprayed more than 9 feet above ground. The average number of flies caught daily each week is recorded in Table XXIX.

TABLE XXIX.—*Number of Mediterranean fruit flies caught in 145 and 147 traps hung in sprayed and unsprayed areas, respectively; spraying begun July 17, ended Aug. 28, 1913.*

Date.	Average number of flies caught each day during week ending.		Date.	Average number of flies caught each day during week ending.	
	Sprayed area.	Unsprayed area.		Sprayed area.	Unsprayed area.
July 5.....	1,191	769.2	Aug. 23.....	215.8	561.8
July 12.....	881.4	722.5	Aug. 30.....	111.1	439
July 19.....	936	769.4	Sept. 6.....	102.7	315.5
July 26.....	541.2	727.2	Sept. 13.....	71.2	219.1
Aug. 2.....	472.5	904.5	Sept. 20.....	76.5	151.8
Aug. 9.....	383.8	937	Sept. 27.....	90	141.2
Aug. 16.....	269.4	762.8			

The data show that the number of flies caught in the sprayed area was greatly reduced by the spraying. The reduction in flies was not great enough, however, to save fruit of any host ripening from becoming badly infested. Similar experiments conducted during May and June, 1914, in an attempt to protect peaches ripening in town door-yards were failures. Of several thousand fruits only three reached maturity uninfested.

The composition of the poisoned-bait spray used against the Mediterranean fruit fly consists of some poison, a sweet substance attractive to the adults, and water. Mally in 1909 used the following formula: Sugar, 3 pounds; arsenate of lead, 4 ounces; water, 5 gallons. He found that from 1 to 1½ pints were sufficient for the average 10-year-old peach or nectarine tree. Lounsbury in his town demonstration work used a spray consisting of 6 pounds brown sugar, 6 ounces arsenate of lead paste, and 8 gallons water. Weinland used a spray of 3½ pounds lead arsenate paste, 10 pounds brown sugar, 5 gallons plantation molasses, and 50 gallons water. Severin used the Mally formula, but increased the lead arsenate from 3 to 5 ounces. The writers used the formula of Weinland.

The writers believe that poisoned-bait sprays if carefully applied under such commercial conditions as exist in California and Florida would prove successful. Their observations indicate that honeybees are in no way affected by these sprays. It is doubtful, however, if poisoned-bait sprays will ever be practical under present-day cultural conditions in Hawaii, where no fruit crop is grown commercially, where the majority of host fruits are either inedible or not worth the cost of spraying, and where sources of reinfestation from without are so great. The entire subject of control by spraying with poisoned baits is still open for investigation under varying conditions.

COLD STORAGE.

A discussion of the use to which cold-storage temperatures may be put as an aid in offsetting the disastrous results of attack by the Mediterranean fruit fly was published by the writers¹ in 1916. The experimental work was undertaken primarily with the hope that it would be an aid in solving the discouraging problems of local horticulturists. But whatever its value in this direction, it now appears that the results may be of much greater commercial importance in defining the conditions under which cold-storage temperatures will kill the fruit fly in stored fruits, thus rendering them free from danger as transporters of this pest from one country to another, or even from one infested district to another. It seems reasonable to conclude that sooner or later the certification of properly refrigerated fruit will be practicable. When an association of fruit growers or a community awakens to a realization of the financial value of the cold-storage treatment there is reason to believe it will result in the operation of central refrigeration plants under the supervision of officials whose guarantee will insure that all fruits sent out from the plant are absolutely free from danger as carriers of the Mediterranean fruit fly.

Experimental work in Australia, as an example, has shown that such perishable fruits as peaches and Japanese plums can be placed on the European markets in good condition if sent in cold storage, and such exports have been encouraged under Government guarantees. While cold storage can never lessen the damage already done by larvæ within fruits offered for sale or shipment, and in no way deals with the root of the trouble, as a palliative, guarding fruits against further attack while in storage or transit, it may become of inestimable value. Fruits, such as apples, that contain freshly-laid eggs or very young larvæ may be placed upon the market, provided further fruit-fly development is checked by cold storage.

For the details of the effect of cold-storage temperatures upon the eggs, larvæ, and pupæ of the Mediterranean fruit fly, as well as for

¹ Back, E. A., and Pemberton, C. E., Effect of cold-storage temperatures upon the Mediterranean fruit fly. *Jour. Agr. Research*, v. 5, no. 15, 1916, p. 657-666; Back, E. A., and Pemberton, C. E., Effect of cold-storage temperatures upon the pupæ of the Mediterranean fruit fly. *Jour. Agr. Research*, v. 6, no. 7, 1916, p. 251-260.

historical facts dealing with the use of such temperatures, one should consult the two articles to which reference has been made. Fruits of almost any variety commonly placed in cold storage are held at temperatures varying from 32° to 45° F., with preference shown to a range of 32° to 36° F. By way of general summary of many experiments, including observations upon over 26,000 eggs, 60,000 larvæ, and 173,000 pupæ to determine the effect of such temperatures as 32°, 32° to 33°, 33° to 34°, 34° to 36°, 36°, 36° to 40°, 38° to 40°, and 40° to 45°, it may be said that no stage of the Mediterranean fruit fly can survive refrigeration for seven weeks at 40° to 45° F.; for three weeks at 33° to 40° F., or for two weeks at 32° to 33° F.

EFFECT OF FREEZING TEMPERATURES UPON THE EGG, LARVA, AND PUPA.

The only freezing temperatures available in Hawaii for experimental work with eggs, larvæ, and pupæ were those found in cold-storage plants maintaining rooms for the refrigeration of fish and meat. The temperature of these rooms ranged between 21° and 30° F. though averaging close to 26° F. Out-of-door freezing temperatures have been experienced by the writers on the Island of Hawaii at an elevation of over 8,000 feet, but lasted only for a few hours at a time and occurred on mountain slopes not easily accessible.

THE EGG.

Apples in which fruit-fly eggs had been deposited on November 3, 1914, were placed in cold storage at a temperature varying from 24° to 30° F. Fruit was removed daily for 10 consecutive days and observations made on a total of 5,434 eggs contained within them. No eggs survived more than 7 days of refrigeration at this temperature. Of 507 eggs subjected to 25° F. for one day 414 hatched on removal to normal temperature; 275 of 308 eggs subjected to 24° to 25° F. for 2 days hatched after removal; 588 of 741 eggs hatched on removal after refrigeration for 3 days at 24° to 26° F.; 430 of 748, 65 of 384, 7 of 534, and 1 of 255 eggs hatched on removal after refrigeration at 24° to 30° F. for 4, 5, 6, and 7 days, respectively. All of 606, 624, and 727 eggs removed to normal temperature after 8, 9, and 9 days of similar refrigeration were dead.

In a second experiment carried out during July, 1913, peaches containing eggs were picked promiscuously in the field, and placed in storage at 26° to 30° F. The results were similar to those mentioned above, as 42 of 178, 7 of 10, and 20 of 145 eggs hatched on removal, after refrigeration for 1, 2, and 6 days, respectively; 57, 148, 82, 134, and 14 eggs refrigerated for 7, 9, 10, 11, and 12 days were dead on removal from storage.

THE LARVA.

First-instar larvæ.—A total of 2,116 first-instar larvæ were placed in cold storage at 21° to 28° F. None survived more than 5 days of refrigeration, and the following observations were recorded: 62 of 248 larvæ in refrigeration for 5 days were found living on examination after removal to normal temperature; 297 of 340 survived one day of refrigeration at 22° to 23° F.; 239 of 275 survived two days of refrigeration at 21° to 23° F.; 110 of 243, and 44 of 240 survived refrigeration at 21° to 28° F. for 3 and 4 days, respectively; 264, 132, 213, and 141 larvæ refrigerated for 6, 7, 8, and 9 days, respectively, were dead on removal from storage.

During May, 1913, 500, 119, and 331 pupæ of all ages were placed in cold storage, the temperature varying from 22° to 24° F. for 5, 7, and 12 days, respectively. After removal to normal temperature all pupæ were found to be dead. During July, 1913, 2,000 pupæ of various ages were subjected to a temperature varying from 24° to 30° F. and averaging about 26° F. for 3 to 16 days; none yielded adults after removal from storage even after only 3 days of refrigeration. On June 24, 1913, 2,500 pupæ removed from storage after one month of refrigeration at about 26° F. were found dead.

Pupæ held in refrigeration 4 days at 24° to 30° F. were removed to normal temperature after being held 2 successive days at 33° to 38° F. and 40° to 45° F., respectively, but none yielded adults.

TRAPS.

The idea of exposing in infested areas a substance that will attract both sexes of the Mediterranean fruit fly is an excellent one, and may lead to the discovery of some medium which will prove an effective method of control. It was the writers' idea to simulate, in such a substance, the odor emanating from the male *C. capitata*, but the experiments proved unsuccessful. Severin exposed various oils derived from crude petroleum, but found them ineffective. He also used, without satisfactory results, turpentine, coconut oil, citronella, whale and fish oils, vinegar, and vanilla. Hooper in Western Australia experimented with naphtha and turpentine in 1907 without success, and similar results followed the exposure by Gurney in New South Wales of citronella, linseed, salad, whale, neatsfoot, and fish-oils. Howlett, in India, was able to attract males of *Dacus zonatus* and *D. diversus* by exposing citronella oil. Later he believed that he had found the actual substances which are responsible for the attraction of these two species in isoeugenol and methyleugenol. Three traps containing, in the order mentioned, eugenol, methyl-eugenol, and isoeugenol hung in orange trees in a badly infested area of Honolulu captured in 6 days only 2, 10, and 1 male *C. capitata*, as compared with 77, 153, and 48 males captured in check traps containing kerosene hung within 50 feet of them. These three substances were furnished the writers by Severin, who had received them in turn from Howlett.

Much of the experimental work to which reference has just been made represents but a small amount of that undertaken to determine the effectiveness of traps. It has grown out of the accidental discovery in Australia by a housewife that a coating of kerosene oil, put about a post for the protection of a glass of preserves from ants, was attractive to adult *C. capitata*. This observation led to the heralding, in 1907, of the use of kerosene as a method of control as the "best discovery against the fruit fly in years," and to regulations in Western Australia requiring fruit growers to place from one to two traps in each fruit tree. It is natural that entomologists combating this pest should carry on experiments, but the worthlessness of kerosene as a factor of control was not demonstrated until a considerable literature upon the subject had been published. Kerosene is ineffective, inasmuch as it attracts for the most part only

males. Of 2,639 adults, representing four lots examined by the writers, only eight were females. Only 36 of 10,239 adults captured by Severin were females. Many thousands of adults captured in kerosene oil in connection with the present investigations have demonstrated the worthlessness of kerosene as a factor in reducing the infestation of fruit.

While the use of kerosene to trap the adults of the Mediterranean fruit fly is of no value in checking the ravages of this pest, the writers have made use of the number of males captured in traps to arrive at conclusions regarding the relative abundance of adults in any given area. The use of the kerosene trap for this purpose when supplemented by other observations has a value, provided conclusions are not attempted from too small a number of catches. The writers have data on file covering the number of flies caught in 292 traps for 16 consecutive months. As a rule traps hung in dense foliage of any sort captured more flies, while traps hung on porches and set upon stumps or in other exposed situations from 30 to 80 feet away from foliage captured only an occasional male. It would seem that in countries where host trees and shrubs are less abundant than in Hawaii the number of flies caught could be used as a basis for valuable deductions on such subjects as seasonal abundance and migrations of adults.

Description of trap.—The trap used by the writers is a simple affair consisting of an ordinary pie tin suspended by three tin strips from a tin cone through the top of which extends a wire by which the entire trap may be suspended from a branch. A trap can be made cheaply by any tinsmith. If properly painted, traps will last several seasons. The pan may be removed as often as desired. In Honolulu the oil was replenished every 2 or 3 days. In dry areas no protective covering for the pan containing the oil is needed. Oil to cover the bottom of the container to a depth of one-fourth of an inch is sufficient. The trap should be so long that no oil will spread to the bark of the tree.

SUBMERGENCE IN WATER.

Submergence of host fruits as a method of control has been recommended many times by writers and investigators of fruit flies. Harris recommended weighting sacks of infested fruit and sinking them at sea. Gurney found that larvæ in sea water in test tubes pupated at the surface against the glass and that a large percentage of larvæ in oranges submerged in cold water for 6, 8, 24, and 45 hours survived, pupated, and matured into normally healthy adults, and concluded that no casual treatment such as throwing infested fruit into a stream can be considered an effective method of destroying fruit-fly larvæ. Severin showed that many well-grown larvæ found floating on the top of a barrel of water, into which infested oranges had been thrown 24 hours previous, resumed activity within several hours after being placed on moist filter paper, in spite of the fact

that they were distended and apparently dead when removed from the water. A small percentage of other larvæ taken from the water after 3 days showed traces of life, but no adults developed from the fruit submerged for 4 days.

With the temperature ranging between 67° and 80° F. the writers were able to demonstrate that well-grown larvæ placed in tightly stoppered vials of fresh water died by the end of the third day. Thus 486 of 490 larvæ survived submergence 21 hours, 96 of 100 for 24 hours, and 78 of 100 for 48 hours; two lots of 100 larvæ each submerged 70 and 74 hours, respectively, were dead. It was found, however, that larvæ live longer when placed in water in open vials. Under such conditions certain individuals may remain suspended from the surface film of water much as do mosquito larvæ and pupæ. This is made possible by the circlet of small hairs about the posterior stigmal plates. While larvæ ordinarily become rigid and apparently dead within 2 or 3 hours after submergence in water, larvæ thus suspended were found to remain active for as long as 7 days in one instance. One larva removed to fresh fruit after suspension for 5 days pupated 7 days later and emerged as an adult after 9 days in the pupa stage.

TABLE XXXI.—*Effect of submergence of host fruits in water upon the larvæ of the Mediterranean fruit fly.*

Number hours im- mersed.	Host fruit.	Number of fruits exam- ined.	Dead larvæ.			Living larvæ.		
			First instar.	Second instar.	Third instar.	First instar.	Second instar.	Third instar.
23	Apple.....	4	4	0	64	0	106	18
41		2	104	81	0	0	4	0
72		6	0	91	32	0	0	0
94		8	0	262	107	0	0	0
4		21	0	0	0	0	63	279
22	Winged kamani.....	22	0	0	5	0	113	448
49		23	0	0	88	0	0	51
72		33	0	0	179	0	0	12
96		253	0	0	1,376	0	0	1
98		21	0	0	142	0	0	0
120	Rose apple.....	34	0	0	147	0	0	0
4		4	36	80	0	0	0	0
24		5	0	9	0	0	8	17
70		50	0	0	217	0	0	0
72		1	0	12	0	0	0	0
98	Chinese orange.....	3	0	37	0	0	0	0
18		94	0	123	189	72	97	3
45		39	0	71	163	0	0	0
69		34	0	0	191	0	0	0
72		162	0	0	205	0	0	0
94	Guava.....	50	0	57	98	0	0	0
116		33	0	0	22	0	0	0
18		9	0	63	9	0	51	168
46		4	0	0	45	0	0	3
69		4	0	19	65	0	0	0
94	Strawberry guava.....	7	0	0	61	0	0	0
49		35	0	0	14	0	0	11
72		54	0	17	38	0	0	0
96		107	0	0	37	0	17	0
4		5	28	0	5	0	40	36
74	Orange.....	2	0	9	5	0	0	0
96		6	0	14	87	0	0	0
121		8	0	9	32	0	0	0
66		58	0	0	156	0	0	2
91		50	0	0	422	0	0	0

The examination of various host fruits submerged in ordinary tap water, when the temperature ranged between 67° and 80° F., gave the data recorded in Table XXXI. The data indicate that while larvæ are little affected after 1 or 2 days of submergence, a large percentage are dead after submergence for 3 days. Seventeen second-instar larvæ and 1 third-instar, however, were found living after submergence for 4 days. It is safe to conclude that submergence for 5 days will either kill all larvæ or incapacitate them for further development. It might be added that fruits held in water for as long as 3 to 5 days are, in Hawaii, rendered unfit as food for fruit-fly larvæ after removal from water.

TABLE XXXII.—*Effect of submergence in tap water upon pupæ of the Mediterranean fruit fly.*

Lot number.	Number of pupæ under observation.	Number of days immersed.	Date of pupation.	Date of immersion.	Date of removal.	Number of adult <i>C. capitata</i> emerging.	Number of adult <i>Opitus humilis</i> emerging.	Date of emergence.
1.....	1,016	2	June 14-17	June 24	June 26	650 191 4	3 15 18	June 27-28 June 29. June 30.
						-----	16	July 4.
							1	July 5.
2.....	440	3	do.....	do....	June 27	62 16 1	0 3 0	July 1. July 2. July 3.
						4	0	July 1.
3.....	312	4	do.....	do....	June 28	3 0 0	0 1 0	July 2. July 4.
4.....	410	5	do.....	do....	June 29	0	0	
5.....	258	6	do.....	do....	June 30	1	0	July 7.
6.....	214	7	do.....	do....	July 1	0	0	
						32	0	June 29.
						207	5	June 30.
7.....	950	2	June 17-22	do....	June 26	190 156 39	7 18 8	July 1. July 3. July 4.
						6	0	July 5.
						18	2	July 6.
						64	0	July 1.
8.....	460	3	do.....	do....	June 27	76 41 16	----- ----- -----	July 3. July 4. July 5.
						9	1	July 6.
						3	-----	July 9.
						1	-----	July 1.
9.....	210	4	do.....	do....	June 28	25 23 9	----- 3 2	July 3. July 4. July 5.
						17	-----	July 6.
						19	1	July 7.
						2	1	July 8.
						19	-----	July 3.
10.....	557	5	do.....	do....	June 29	19 42 18	----- ----- -----	July 4. July 5. July 6.
						22	-----	July 7.
						5	-----	July 8.
						13	-----	July 9.
11.....	372	6	do.....	do....	June 30	6 3 3	----- ----- -----	July 7. July 8. July 10.
12.....	476	7	do.....	do....	July 1	0	0	July 12.
Total....	5,675							

Pupæ from 1 to 4 days old were submerged in vials of tap water when the temperature ranged from 72° to 85° F. A record of the

emergence from these pupæ is given in Table XXXII. The data covering lots 1 to 6 show that the more mature pupæ succumbed to immersion more quickly than the younger pupæ of lots 7 to 12. Thus many of the young pupæ emerged as adults after being submerged 4, 5, and 6 days, while submergence for these periods killed nearly all the older pupæ. Submergence for at least 7 days is necessary to assure the death of all pupæ.

BURIAL IN SOIL.

Many entomologists have made statements regarding the efficacy of burying infested fruits in the soil as a method of destroying fruit flies. These references have been summarized by Severin, hence need not be considered at length here, particularly as they deal with a method that is decidedly unsatisfactory and seldom effective. Gurney found that pupæ buried 6, 8, and 12 inches below the surface of the soil produced adults that were able to escape. Severin found that adults could make their way to the surface from pupæ buried 2, 3, and 4 feet beneath dry sand, and from pupæ buried 2 feet beneath wet sand, but that no adults escaped through 2, 3, or 4 feet of dry soil. Mally found that 10 inches of soil shoveled loosely over fruits did not prevent adults from escaping later, but that no adults could reach the surface through 10 inches of well-tamped soil. No adults escaped from 20 pupæ placed in the center of a cake of mud one-half inch square taken from the heavy, tenacious soil of the vegetable gardens at Waikiki. The mud became thoroughly dry without cracks before the end of the normal pupa stage. A cake of the same soil $1\frac{1}{2}$ inches square, however, on drying developed a crack through which 50 adults made their escape from 75 pupæ buried within the center of the square. While adults can not make their way through a foot of well-tamped soil, it is difficult to bury host fruits in such a manner that the soil covering will remain firm. The rapid decay and settling of fruit, if any amount be buried in the same excavation, cause cracks to develop through which adults can escape readily. While many fruit flies can be killed by proper burial, indifference and carelessness among workmen will always make possible the escape of many adults.

BURNING AND BOILING HOST FRUITS.

Burning or boiling host fruits is a sure method of destroying the immature stages of the Mediterranean fruit fly provided the work is feasible and can be done thoroughly. The usual practice of throwing fallen infested fruits into a compost pit and burning over them every few days such trash as may have accumulated is not a trustworthy method of destruction, inasmuch as the heat produced is very often insufficient to cook or burn the fruit thoroughly or to reach the pupæ in the soil beneath the fruit.

SUMMARY.

The Mediterranean fruit fly (*Ceratitis capitata*) was discovered at Honolulu in the Hawaiian Islands in 1910. Since that time it has spread to all the islands of the Hawaiian group, and because of the equable climate and abundance of host fruits, has effected a serious and permanent check to horticultural pursuits, and put an end to all export trade in fruits except that in bananas and pineapples.

Research seems to have fixed the native home of *C. capitata* in tropical Africa. Its spread has been slow but persistent throughout tropical and semitropical countries, until at the present time it is known to have become a pest in every continental area except that of North America. With the Mediterranean fruit fly now well established in Bermuda and the Hawaiian Islands, it would seem that it is only a matter of time before it will be inadvertently introduced and become established in California and the Southern States. The frequent interception and destruction of infested fruits from Hawaii at California ports, by officers of the Federal Horticultural Board, indicates the ease with which the introduction of the Mediterranean fruit fly might occur were Hawaiian fruit permitted unrestricted entry to the mainland of the United States.

No edible fruit in Hawaii, except the pineapple, escapes attack. The banana, when in good condition, is never infested, infestation having been noted only when the fruits were overripe or injured. The Mediterranean fruit fly has been reared in Honolulu from 72 species of host fruits, including the peach, plum, pear, guava, mango, orange, lemon, grapefruit, banana, etc. A large proportion of the host fruits are inedible. Throughout the littoral regions a continuous cycle of host fruits is available for infestation throughout the year; hence there are no starvation periods for the fly to survive.

With such a quantity and variety of host fruits, nuts, and vegetables in which to propagate, and enjoying an ideal climate, the mean temperatures of which vary between 68° and 79° F. for the regions in which the fly is a most serious pest, the Mediterranean fruit fly finds no check to its rapid increase. While a single generation may require as few as 17 days during the warmest weather, there are usually 15 to 16 generations a year at Honolulu, and 10 to 12 generations in areas where the winter mean drops to 68° F. There is considerable variation in the length of the immature stages, particularly during the coolest weather. Inasmuch as adults have been kept alive for 10 months and may deposit eggs in lots of a few to 32 daily quite regularly throughout life, the generations become hopelessly confused. While adults are not forced in Hawaii to pass through periods of several months when food is not available for oviposition, females deprived of host fruits for such periods will resume active and normal oviposition when the fruits become avail-

able. One female deposited 622 eggs between June 4 and September 2. The long adult life, and the ability of the female to deposit eggs regularly succeeding the period of from 4 to 8 days after emergence which is required to complete sexual maturity, make it possible for the annual progeny of a single pair of adults to reach enormous numbers.

Attempts at control by clean culture have been failures, owing largely to insurmountable obstacles placed in the way of man by a favorable climate and an unprecedented quantity of varied host fruits. Many fruits and nuts subject to attack grow on huge trees which blossom irregularly, and produce, in many instances, fruit susceptible to attack throughout the year. There is no procedure by which clean culture may be made effective under the present Hawaiian cultural methods. The islands are thoroughly overrun with the fruit fly, and this applies quite as much to the wild guava scrub in pastures, on lava flows, and in mountain valleys and ravines, as it does within the city limits. By far the larger number of host trees and shrubs are grown more for the protection they offer from the semitropical sun and for their ornamental value than for their inedible fruits. The destruction of host vegetation will not be practicable until it can be demonstrated that a distinct advantage would be gained thereby. To destroy all host trees of Honolulu at the present time would be to remove a large percentage of her prized vegetation without any compensating returns.

The ideal climatic and host conditions of Hawaii have rendered less effective and impracticable the usual artificial methods of control the value of which has been demonstrated in other countries possessing natural features less favorable to fruit-fly increase. At the present time the only hope of relief lies in the establishment of parasites. Six parasites have been introduced during the past three years and are now well established. While they have more than repaid the Territory of Hawaii for the cost of their introduction by bringing about an improved condition in the coffee-growing industry, it is doubtful whether they will effect a sufficient decrease in the proportion of infested host fruits to be considered efficient factors in control. This conclusion appears inevitable in spite of the remarkable success attendant on their introduction, unless a campaign is inaugurated for a reapportionment of host fruits; otherwise the hordes of adult flies maturing in thick-meated fruits, or in fruits protecting larvæ by other means from attack by parasites, will neutralize the effective work of parasites attacking larvæ in thin-skinned and thin-pulped fruits. There is great need of an effective egg parasite that will kill the fruit fly before the larva can do injury.

From a practical or commercial standpoint the results of the investigations reported herewith are of value (1) in furnishing data to

determine the probable range of this pest should it be introduced and gain a foothold in continental United States; (2) in verifying the practicability of poison sprays; (3) in indicating the utilization of cold-storage temperatures in making safe the movement of fruits from areas which might otherwise be cut off by quarantines from outside markets; and (4) in placing upon a sound basis the banana and pineapple export trade of the Hawaiian Islands.

At 50° F. little if any development takes place, and freezing temperatures can be withstood successfully only for short periods. Accumulated data indicate that the Mediterranean fruit fly will not become a serious pest in climates where the mean temperature is below 50° F. during periods covering three months of the year.

While Hawaiian conditions are unfavorable to the use of poison sprays, the work of the writers has convinced them that these sprays can be employed as successfully in combating this pest in commercial orchards of California and of Southern States, should they ever become infested, as in Africa and Australia.

While at present cold storage is not utilized to modify existing quarantine, it is a recognized fact that, commercially used, it has been of value in safeguarding fruits from additional infestation while en route over long distances. The data set forth herewith indicate for the first time the duration of time required for various temperature ranges to kill the stages of the fruit fly within stored fruits, and from these records it is reasonable to conclude that the certification of properly refrigerated fruit is practicable. When an association of fruit growers or the people discover that refrigeration is financially worth while, there is reason to believe that it will result in the operation of central refrigeration plants under the supervision of officers whose guarantee will insure that all fruits sent out from the plant are absolutely free from danger as carriers of the Mediterranean fruit fly.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 537

Contribution from Office of Public Roads and Rural Engineering.
LOGAN WALLER PAGE, Director.



Washington, D. C.

PROFESSIONAL PAPER

April 21, 1917

THE RESULTS OF PHYSICAL TESTS OF ROAD-BUILDING ROCK IN 1916, INCLUDING ALL COMPRESSION TESTS.

By PRÉVOST HUBBARD, *Chemical Engineer*, and FRANK H. JACKSON, JR., *Assistant Testing Engineer*.

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INTRODUCTION.

This bulletin should be considered as a supplement to United States Department of Agriculture Bulletin 370, which gives the results of the more common physical tests of some 3,650 road-building rock examined by the Office of Public Roads and Rural Engineering to January 1, 1916. The office tested 396 samples of rock in 1916, the results of which tests are given in Table I, the rocks being classified according to their location. It should be noted that in a number of cases, in addition to other tests, the crushing strength of the rock also is given. This test is not made ordinarily when examining rock to determine its suitability for use in various types of broken-stone roads. The test is employed often, however, when considering a rock for use in the manufacture of paving block, and as many requests for records of the crushing strength of various rocks have been received in the past year, it has been thought advisable to give in Table II a complete record of all of the crushing-strength tests made by the office up to January 1, 1917. Following is a brief description of this test, as made by the office.

CRUSHING STRENGTH OR COMPRESSION TEST.

The compression test is made upon a cylindrical test specimen 2 inches in diameter and 2 inches high. Both ends of the specimen, which have been sawed at right angles to the axis of the cylinder,

and properly faced, are bedded in plaster of Paris. The cylinder then is crushed in a 200,000-pound universal testing machine. A small 2-inch spherical bearing block is placed between the moving head of the machine and the upper surface of the specimen. The average of at least two determinations is reported as the crushing strength, calculated in pounds per square inch. Crushing strength tests are made upon samples of road-building rock only when especially requested. Of a total of 282 compression tests made up to January 1, 1917, Table II shows that 97 were made on granites, 13 on gneisses, 78 on limestones, 42 on dolomites, 28 on sandstones, and 24 on various other types of material.

The percentage variation in the strength of the 110 granites and gneisses and the 120 limestones and dolomites is shown graphically

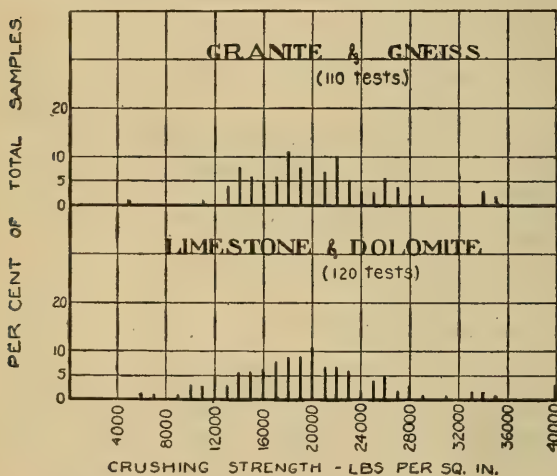


FIG. 1.—Variations in the crushing strength of rock.

in figure 1. In this chart the per cent of total samples tested having various values for crushing strength are plotted as indicated. For instance, the chart shows that 10 per cent of all granites and gneisses tested show a crushing strength of 20,000 pounds per square inch. Likewise, by summing up all the per cents to the left of the 20,000-pound line we find that 48 per cent of all samples of granite and gneiss tested have a crushing strength of less than 20,000 pounds per square inch, which shows that the average crushing strength of this type of material lies between 19,000 and 20,000 pounds per square inch. Likewise, the average crushing strength of the limestones and dolomites lies between 18,000 and 19,000 pounds per square inch.

INTERPRETATION OF RESULTS OF PHYSICAL TESTS.

A discussion of the interpretation of the results of physical tests was given in Bulletin 370, to which reference has been made. Since the publication of that bulletin, however, a table of general limiting test values for broken stone for various types of road construction has been adopted by the office and printed on the back of its form for reporting tests. For general reference these limiting values, together with comments upon limits shown, are given in Table IV.

TABLE I.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, from Jan. 1, 1917, to Jan. 1, 1917.

Serial No.	Town or city.	County.	Name of material.	Crushing strength, per square inch.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
10138	Bridgeport.	Jackson.	Oolitic limestone.	(1)	Pounds, 168	0.21	4.4	9.1	15.7	5	41
9985	Birmingham.	Jefferson.	Limestone.	(1)	168	.55	5.0	8.0	15.3	6	40
ARKANSAS.											
9828	Lamar.	Johnson.	Feldspathic sandstone.	21,980	159	1.98	(1)	(1)	18.7	13	17
9838	Fort Smith.	Sebastian.	Sandstone.	(1)	150	5.00	6.5	6.2	15.3	6	25
10486	Gillham.	Sevier.	Feldspathic quartzite.	(1)	164	.42	2.3	17.4	19.0	32	(1)
COLORADO.											
9821	Lyons (near)	Boulder.	Argillaceous limestone.	(1)	162	2.98	4.9	8.2	15.3	7	162
9822	Lyons.	do.	Sandstone.	(1)	156	1.73	3.4	11.8	18.3	11	36
9823	Lyons (near)	do.	do.	(1)	156	1.37	2.7	13.8	16.0	14	13
11168	Denver.	Jefferson.	Augite andesite.	(1)	169	1.27	7.6	14.8	15.3	17	98
11169	do.	Denver.	Smelter slag.	(1)	216	.65	7.6	5.3	(1)	(1)	6
11170	do.	do.	do.	(1)	217	.50	5.1	7.8	(1)	(1)	7
11171	do.	do.	do.	(1)	217	.86	4.6	8.7	17.3	15	4
CONNECTICUT.											
9944	Plainville.	Hartford.	Diabase.	(1)	184	1.14	2.0	20.0	19.0	23	102
11151	East Haven.	New Haven.	Altered basalt.	(1)	169	.63	3.7	10.8	17.3	10	72
11067	Waterford.	New London.	Granite.	21,840	162	1.74	(1)	(1)	18.7	13	(1)
11068	do.	do.	Biotite granite.	23,850	162	.78	(1)	(1)	18.7	8	(1)
11069	do.	do.	do.	22,170	164	.71	(1)	(1)	18.7	14	(1)
9791	Oneco.	Windham.	do.	16,635	(1)	(1)	(1)	(1)	18.3	8	(1)
11098	do.	do.	do.	23,290	164	.55	(1)	(1)	18.7	6	(1)
11099	do.	do.	Gneissoid granite.	20,200	163	.67	(1)	(1)	18.7	6	(1)
11148	do.	do.	do.	20,825	163	.44	4.6	8.7	18.7	7	(1)

1 Test not made.

2 Exact locality not known.

TABLE I.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, from Jan. 1, 1916, to Jan. 1, 1917*—Con.

FLORIDA.

Serial No.	Town or city.	County.	Name of material.	Crushing strength, per pounds per square inch.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
10776	(2)	Broward.	Siliceous limestone.....	(1)	Pounds.	Pounds.	(1)	(1)	17.3	6	61
10411	Delray (3 miles west).....	Palm Beach.....	Shell limestone.....	(1)	(1)	(1)	50.9	0.8	(1)	(1)	52
10430	Boynton (near).....	do.....	do.....	(1)	(1)	(1)	37.2	1.1	(1)	(1)	40
10431	Jupiter (15 miles west).....	do.....	Siliceous limestone.....	(1)	(1)	(1)	12.5	3.2	14.7	5	43

GEORGIA.

10398	Cartersville (3 miles east).....	Bartow.....	Quartz schist.....	(1)	159	0.71	5.0	8.0	19.3	11	(1)
10399	Cartersville.....	do.....	Ferruginous sandstone.....	(1)	145	8.74	22.0	1.8	(1)	(1)	(1)
10400	Cass Station (2 miles north).....	do.....	Sandstone.....	(1)	152	2.86	(1)	(1)	18.7	12	(1)
10192	Titusville.....	Brevard.....	Shell limestone.....	(1)	155	4.03	7.5	5.3	14.9	2	42
10145	Carrollton (4 miles north).....	Carroll.....	Biotite gneiss.....	(1)	172	.35	4.7	8.5	17.7	7	(1)
10646	Carrollton.....	do.....	Granite gneiss.....	(1)	165	.62	4.5	8.9	18.7	5	(1)
10647	Carrollton (2 miles south west).....	do.....	do.....	(1)	169	.51	4.6	8.7	18.5	6	(1)
10648	Carrollton.....	do.....	do.....	(1)	168	.53	4.8	8.3	18.7	4	(1)
10654	Carrollton (7 miles northeast).....	do.....	Biotite gneiss.....	(1)	166	.67	(1)	(1)	18.0	10	(1)
10655	Temple (4 miles east).....	do.....	do.....	(1)	169	.56	7.7	5.2	17.0	5	(1)
10649	Carrollton (4 miles southeast).....	do.....	Biotite schist.....	(1)	168	.51	5.7	7.0	18.9	8	(1)
10631	Maury.....	do.....	Epidote hornblende schist.....	(1)	192	1.12	5.5	7.3	17.7	9	(1)
10653	Roopville.....	do.....	Mica schist.....	(1)	168	.75	(1)	(1)	16.7	5	(1)
10657	Bowdon (1 mile north).....	do.....	Amphibolite.....	(1)	187	1.20	19.0	2.1	10.5	4	(1)
10417	Athens.....	Clarke.....	Biotite granite.....	(1)	163	.68	6.4	6.3	18.7	6	(1)
10422	Athens (4 miles west).....	do.....	do.....	(1)	163	1.56	(1)	(1)	15.4	4	(1)
10423	Athens (4 miles from).....	do.....	do.....	(1)	167	.58	4.4	9.1	17.8	9	(1)
10420	Athens.....	do.....	Granite gneiss.....	(1)	169	.76	5.9	6.8	18.7	4	(1)
10418	do.....	do.....	Biotite gneiss.....	(1)	167	.65	7.5	5.3	17.7	6	(1)
10421	Athens (south of).....	do.....	do.....	(1)	167	.67	(1)	(1)	18.3	6	(1)
10377	Marietta (11 miles south).....	Cobb.....	do.....	(1)	170	.67	6.5	6.2	17.3	6	(1)
10378	Charltonochee River.....	do.....	do.....	(1)	165	.26	5.1	7.8	18.6	8	(1)
10380	Last Mountain Store.....	do.....	Hornblende gneiss.....	(1)	188	.93	(1)	(1)	13.3	4	(1)
10381	Southeast Kennesaw Mountain.....	do.....	Feldspathic gneiss.....	(1)	167	.73	(1)	(1)	18.7	6	(1)
10382	Marietta (4 miles north west).....	do.....	Biotite gneiss.....	(1)	169	.68	5.6	7.1	17.3	6	(1)
10387	Aacworth (4 miles south).....	do.....	do.....	(1)	175	.59	10.1	3.9	16.7	5	(1)
10388	Aacworth (4 miles south).....	do.....	do.....	(1)	174	.59	10.1	3.9	16.7	5	(1)
10389	Austell (4 mile west).....	do.....	Granite gneiss.....	(1)	163	.50	7.4	5.4	18.7	5	(1)

10393	Blackwell Station (1 mile north)	do.	Horblende gneiss.	17,350	184	.42	4.9	8.2	17.3	(1)
10394	Kennesaw Mountain (north of)	do.	do.	(1)	180	1.05	(1)	(1)	18.0	(1)
10397	Snyrna (3½ miles west)	do.	Magnetic quartzite.	(1)	172	180	(1)	(1)	18.0	(1)
10395	Kennesaw Station (4 miles southwest)	do.	Amphibolite.	(1)	191	.46	5.3	7.5	15.3	20
9869	do.	Decatur.	Siliceous shell limestone.	(1)	125	2.51	22.2	1.8	19.3	20
10197	Beach Creek Bridge.	Floyd.	Calcareous shale.	(1)	163	2.14	(1)	(1)	10.7	(1)
10199	Lavender Mountain.	do.	Sandstone.	(1)	163	1.47	(1)	(1)	17.7	29
10198	Hufaker Station.	do.	Limestone.	(1)	170	.22	3.6	11.1	16.0	6
10200	Dome (3 miles north).	do.	Argillaceous limestone.	(1)	168	.21	5.1	7.8	15.7	42
10202	Rozar Creek.	do.	Limestone.	(1)	170	.44	5.1	7.8	15.7	36
10203	Pinson.	do.	do.	(1)	169	.22	4.9	8.2	15.3	39
10211	Rome.	do.	Argillaceous limestone.	(1)	167	.95	5.6	7.1	14.7	35
10221	Armuchee (1 mile southeast).	do.	Crystalline limestone.	(1)	168	.35	5.5	7.3	15.0	38
10222	do.	do.	Oolitic limestone.	(1)	168	.20	4.2	9.5	16.0	8
10223	do.	do.	Limestone.	(1)	168	1.12	3.8	10.5	16.7	8
10224	Armuchee (southeast of).	do.	Argillaceous limestone.	(1)	167	.59	4.0	10.0	17.3	16
9761	Atlanta (near).	Fulton.	Biotite granite.	(1)	168	.32	3.7	10.8	18.3	7
9764	Atlanta.	do.	Gneissoid granite.	(1)	165	.34	4.7	8.5	18.0	7
9753	Atlanta (near).	do.	do.	(1)	162	.85	(1)	(1)	19.3	8
9752	do.	do.	Granite gneiss.	(1)	168	.35	3.8	10.5	(1)	(1)
9754	do.	do.	Biotite gneiss.	(1)	165	.53	(1)	(1)	18.7	9
9755	do.	do.	Mica gneiss.	(1)	165	.34	8.4	4.8	17.3	7
9756	Atlanta (near).	do.	Granite gneiss.	(1)	165	.30	4.3	9.3	18.7	10
9757	do.	do.	do.	(1)	165	1.01	(1)	(1)	18.7	15
9758	do.	do.	do.	(1)	165	.41	4.1	9.8	17.2	7
9759	Atlanta.	do.	do.	(1)	165	.30	3.8	10.5	19.3	13
9760	Atlanta (near).	do.	do.	(1)	165	.40	3.5	11.4	18.3	20
9762	do.	do.	Biotite gneiss.	(1)	172	1.03	(1)	(1)	18.3	9
9763	do.	do.	Horblende gneiss.	(1)	184	.77	(1)	(1)	19.0	32
9765	do.	do.	Biotite gneiss.	(1)	165	.18	5.0	8.0	18.7	6
9766	Atlanta.	do.	Granite gneiss.	(1)	165	.36	3.4	11.8	18.0	29
9767	do.	do.	Horblende biotite gneiss.	(1)	175	.26	4.4	9.1	16.7	6
10396	Fairmount (½ mile south).	Gordon.	Limestone.	(1)	169	.27	5.3	7.5	14.7	22
10397	do.	do.	do.	(1)	170	.08	4.1	9.8	15.3	31
10547	Lawrenceville.	Gwinnett.	Biotite hornblende schist.	(1)	183	.60	(1)	(1)	15.7	35
10556	do.	do.	do.	(1)	183	.60	(1)	(1)	15.7	(1)
10553	Lawrenceville.	do.	Horblende schist.	(1)	196	.65	6.6	6.1	(1)	(1)
10564	Rosebud.	do.	Granite gneiss.	(1)	159	.62	4.4	9.0	17.0	(1)
10565	Shelville.	do.	Biotite gneiss.	(1)	162	.69	5.6	7.1	18.9	(1)
10564	Lawrenceville.	do.	do.	(1)	162	.73	5.5	7.3	17.3	(1)
10555	Lawrenceville.	do.	Granite.	(1)	165	.33	5.9	6.8	19.2	(1)
10555	Lawrenceville (1½ miles east).	do.	do.	(1)	162	.86	(1)	(1)	17.7	(1)
10557	Lawrenceville (6 miles south-east).	do.	do.	(1)	162	.72	4.9	8.2	18.4	(1)
10558	do.	do.	do.	(1)	162	.61	4.6	8.7	18.0	(1)
10559	Grayson (2 miles east).	do.	Biotite granite.	(1)	158	.71	5.7	7.0	18.0	(1)
10560	McPhanney Shoals.	do.	Gneissoid granite.	(1)	162	.71	5.2	7.7	18.2	(1)
10561	Grayson (southwest of).	do.	do.	(1)	162	.67	6.7	7.7	17.5	(1)
10562	Langley Quarry.	do.	Granite.	(1)	162	.82	6.7	6.0	17.5	(1)

Exact locality not known.

Test not made.

TABLE I.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, from Jan. 1, 1916, to Jan. 1, 1917—Con.*

GEORGIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Crushing strength, pounds per square inch.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
					Pounds.						
10543	Grayson (3 miles southwest)	Gwinnett	Granite.	(1)	112	0.78	5.5	7.3	18.3	6	(1)
10544	Snellville (2 miles southeast)	do	do.	(1)	102	.73	4.0	10.0	18.3	6	(1)
10545	Lawrenceville (4 miles west)	do	Amphibolite.	(1)	190	.92	3.4	11.8	18.0	13	12
10546	Penderrass.	Jackson	Olivine diabase.	(1)	184	.09	3.6	11.1	18.0	10	22
10547	Talmo.	do	Granite gneiss.	(1)	161	1.13	7.6	5.2	(1)	5	(1)
10548	Hollier Sidm (near)	do	Hornblende gneiss.	(1)	165	.48	4.0	10.0	18.3	7	(1)
10549	Jefferson (4 miles north)	do	Granite.	(1)	163	.63	5.6	7.1	18.3	5	(1)
10550	Jefferson (3 miles east)	do	Hornblende schist.	(1)	180	.04	(1)	(1)	17.0	4	(1)
10551	Robertsville (1½ miles north-east)	Jones	Argillaceous sandstone.	(1)	105	19.80	12.2	3.2	(1)	(1)	(1)
9739	Montbrook.	Levy.	Chert.	(1)	156	2.02	3.2	12.5	(1)	(1)	8
9740	do.	do.	do.	(1)	156	2.74	3.5	11.4	(1)	(1)	78
10384	Upper Marietta.	Milton	Granite gneiss.	(1)	167	.56	6.6	6.1	18.0	8	(1)
10385	do.	do.	do.	(1)	163	.59	6.9	5.8	18.7	6	(1)
10386	Columbus (4 miles north).	Muscogee	Hornblende gneiss.	(1)	179	.25	4.5	8.9	16.7	5	(1)
10387	do.	do.	do.	(1)	179	.45	5.0	8.0	16.7	5	(1)
10388	Fortson (4 miles south).	do	Biomite gneiss.	(1)	167	.48	3.7	10.8	18.7	10	(1)
10389	Fortson (1 mile southwest)	do	do.	(1)	164	.89	5.3	7.6	18.7	9	(1)
10390	Gentian (3½ miles northeast).	do	do.	(1)	163	.50	3.6	11.1	18.7	9	(1)
10391	Columbus (8 miles north).	do	Granite gneiss.	(1)	163	.83	4.3	9.3	18.7	7	(1)
10392	Gentian (3½ miles northeast).	do	Hornblende gneiss.	(1)	163	.58	3.7	10.8	18.7	10	(1)
10393	Gentian (3½ miles northeast).	do	Granite gneiss.	(1)	165	.36	3.9	10.2	18.7	7	(1)
10394	Columbus (east of).	do	Biomite granite.	(1)	165	.40	4.2	9.5	18.7	8	(1)
10395	Fortson (2 miles southeast).	do	Siliceous limestone.	(1)	108	(1)	(1)	(1)	17.3	6	(1)
10776	(2).	(2).		(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
IDAHO.											
10462	St. Anthony	Fremont	Basalt.	(1)	159	4.17	7.2	5.6	16.7	4	(1)

ILLINOIS.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Aurora.....	9750	Kane.....	Smelter slag..	221	0.17	2.2	18.2
03037	Kankakee.....	Dolomite.....	11,180	158	2.12	8.4	16.0
02098	Fox Township.....	Kendall.....	do.....	169	1.67	4.9	13.3
11133	Pontiac.....	do.....	Argillaceous limestone.	156	2.73	12.9	(1)
9827	Joliet.....	Livingston.....	Dolomite.....	168	1.18	8.2	15.1
10772	Aurora.....	Will.....	Smelter slag..	212	0.00	7.3	18.7
		do.....	do.....				

INDIANA,

9688	(2).....	Clark.	Argillaceous dolomite.	(1)	150	5.23	10.3	3.9	0.0	3
9689	Brazil.	Clay.	Limestone.	(1)	174	.60	4.3	9.3	17.3	11
1082	Miltozn.	Crawford.	do.	(1)	167	.56	3.3	12.1	16.3	34
1018	do.	do.	do.	(1)	168	.66	3.6	11.1	15.0	31
1019	do.	do.	do.	(1)	167	.60	3.5	11.4	15.3	28
1021	do.	do.	Argillaceous limestone.	(1)	168	1.17	3.0	13.3	15.3	36
1020	do.	do.	Limestone.	(1)	168	.37	4.5	8.9	16.7	35
1022	do.	do.	do.	(1)	168	.61	4.4	9.1	15.7	13
1023	do.	do.	Pisolitic limestone.	(1)	158	2.78	5.2	7.7	8.7	13
1024	do.	do.	Limestone.	(1)	161	2.59	4.5	8.9	14.7	21
1025	do.	do.	Argillaceous limestone.	(1)	168	2.01	4.4	9.1	14.0	23
St. Paul.	Decatur.	do.	do.	(1)	168	1.01	4.0	10.0	13.3	32
0114	do.	Dubois.	Siliceous limestone.	(1)	169	2.58	3.8	10.5	16.3	43
1066	Schnellville.	Huntington.	Dolomite.	25, 420	163	2.10	4.1	9.7	14.0	95
1183	Huntington.	do.	do.	(1)	159	4.30	5.0	8.0	15.3	9
9811	Vernon.	Jennings.	Limestone.	(1)	167	2.08	3.9	10.2	15.3	63
0834	do.	do.	Polorite.	(1)	149	6.90	8.1	4.9	12.0	37
0847	do.	Monroe.	Limestone.	(1)	(1)	(1)	(1)	(1)	(1)	4
0256	Bloomington (east of).	do.	Argillaceous limestone.	(1)	185	1.03	4.8	8.3	12.0	5
0257	Bloomington.	do.	Limestone.	(1)	188	.66	(1)	(1)	14.7	5
0493	do.	Futnam.	do.	(1)	139	2.22	(1)	(1)	16.7	22
9660	Greencastle.	do.	Argillaceous limestone.	(1)	162	2.00	(1)	(1)	11.2	22
0519	Fillmore.	do.	do.	(1)	160	1.07	7.3	5.5	12.0	18
0520	do.	do.	Limestone.	(1)	159	3.81	4.5	8.9	9.0	26
0727	Greencastle.	do.	do.	(1)	165	2.89	6.2	6.5	15.3	3
0020	Elberfeld.	Warrick.	Dolomite.	(1)	166	1.24	5.4	7.5	15.0	45
9935	Bluffton.	Wells.	Limestone.	(1)	166	1.24	5.4	7.5	15.0	8
0693	do.	(2).	Argillaceous limestone.	(1)	148	8.75	8.9	4.5	13.5	52
0694	do.	(2).	do.	(1)	148	8.75	8.9	4.5	0.0	49

KANSAS.

9599	Fort Scott (7 miles west of).....							
9780	Beloit.....							
	Bourbon.....							
	Mitchell.....							
	Limestone breccia.....	7,380	(1)					
	Argillaceous limestone.....	143	(1)					
		6.71	(1)					
		18.2	(1)					
		2.2	(1)					
		4.3	(1)					
				(1)				
					(1)			
						(1)		
							(1)	
								(1)
								33

Test not made.

² Exact locality not known.

TABLE I.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, from Jan. 1, 1916, to Jan. 1, 1917—Con.

KENTUCKY.

Serial No.	Town or city.	County.	Name of material.	Crushing strength, per square inch.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
10134	Lexington.....	Fayette.....	Argillaceous limestone.....	(1)	Pounds. 168	Pounds. 0.19	6.1	6.6	16.0	4	41
10136	do.....	do.....	do.....	(1)	168	.17	5.5	7.3	12.7	4	34
10451	Cerulean Springs (near).....	Trigg.....	do.....	(1)	167	.45	4.7	8.5	14.2	6	37
9829	(2).....	(2).....	Limestone.....	(1)	165	1.31	(1)	(1)	13.7	6	40
9830	(2).....	(2).....	Argillaceous limestone.....	(1)	165	.82	(1)	(1)	15.5	10	44

MAINE.

10219	North Jay.....	Franklin.....	Granite.....	21,260	164	0.84	2.7	14.8	19.3	7	13
9997	Mount Desert.....	Hancock.....	do.....	19,780	165	.21	3.4	11.8	19.7	9	11
10233	do.....	do.....	do.....	19,220	162	.90	4.1	9.8	18.7	8	9
10234	do.....	do.....	do.....	24,700	160	.67	3.2	12.5	18.7	12	14
10288	Ship Harbor.....	do.....	do.....	28,650	165	.21	(1)	(1)	19.3	18	(1)
10989	do.....	do.....	do.....	26,500	163	.31	(1)	(1)	18.7	13	(1)
10990	do.....	do.....	do.....	32,450	164	.42	(1)	(1)	19.3	16	(1)
9781	St. George.....	Knox.....	do.....	18,780	(1)	(1)	(1)	(1)	(1)	12	(1)
9865	do.....	do.....	do.....	17,150	(1)	(1)	(1)	(1)	18.8	9	(1)
10019	Vinal Haven.....	do.....	Biotite granite.....	21,650	165	.25	3.1	12.9	19.3	14	28
9996	do.....	do.....	Granite.....	17,540	168	.23	3.3	12.1	19.2	10	30
10249	Long Cove.....	do.....	Biotite granite.....	22,500	165	.86	3.0	13.3	19.3	13	(1)
10240	do.....	do.....	Granite.....	22,330	166	.82	3.5	11.4	19.3	8	(1)
9706	Rockland.....	do.....	Marble.....	(1)	175	.40	4.3	9.3	17.0	4	47

MARYLAND.

10105	Frederick.....	Frederick.....	Limestone.....	(1)	(1)	(1)	3.0	13.3	16.0	5	(1)
10021	North Laurel.....	Howard.....	Amphibolite.....	(1)	200	0.46	3.5	11.4	17.7	8	32
10101	Dickerson.....	Montgomery.....	Diabase (trap).....	(1)	(1)	(1)	1.4	28.6	18.5	21	(1)
11153	Halpine.....	do.....	Biotite granite.....	(1)	171	.42	3.1	12.9	18.7	13	(1)
11152	do.....	do.....	Epidote hornblende gneiss.....	(1)	198	.65	3.1	12.9	16.0	11	(1)

MASSACHUSETTS.

10016	Great Barrington.....	Berkshire.....	Marble.....	(1)	175	0.37	5.6	7.1	15.3	4	43
10288	Otis.....	do.....	Granite.....	18, 280	166	.71	2.6	15.4	18.0	9	(1)
9770	Fall River.....	Bristol.....	Biotite gneiss.....	(1)	178	.27	2.7	14.8	18.2	17	(1)
11017	Aushnet.....	do.....	Chlorite gneiss.....	(1)	167	.44	2.4	16.6	19.0	17	(1)
10247	Seekonk.....	do.....	Feldspathic sandstone.....	(1)	167	.76	4.0	10.0	18.7	12	17
9649	Essex.....	do.....	Granite.....	19, 580	165	.32	3.7	10.8	19.7	10	9
9650	do.....	do.....	do.....	18, 125	165	.35	4.4	9.1	18.7	10	17
9651	do.....	do.....	do.....	22, 285	165	.33	4.9	8.2	19.3	7	13
9652	do.....	do.....	do.....	18, 780	165	.21	3.6	11.1	19.3	11	13
10089	West Rutland.....	Worcester.....	do.....	(1)	164	.16	2.9	13.8	18.6	12	19
10090	do.....	do.....	do.....	(1)	161	.79	6.7	6.0	18.0	7	18
10091	do.....	do.....	Biotite gneiss.....	(1)	168	.89	6.5	6.2	16.3	9	35
10935	Fayetteville.....	do.....	Granite gneiss.....	(1)	162	.75	3.0	13.3	18.7	11	(1)

MICHIGAN.

9855	Marquette.....	Marquette.....	Hornblende gneiss.....	(1)	184	0.62	(1)	(1)	19.3	22	30
9857	do.....	do.....	Amphibolite.....	(1)	181	.57	(1)	(1)	18.0	17	49
9856	do.....	do.....	Altered diabase.....	(1)	184	.66	(1)	(1)	18.7	25	32
9975	do.....	do.....	do.....	(1)	181	.52	2.1	19.1	19.3	12	27
9976	do.....	do.....	do.....	(1)	175	.42	3.8	10.5	16.0	13	55
9977	do.....	do.....	do.....	(1)	184	.60	3.1	12.9	18.3	11	97
9977	do.....	do.....	do.....	(1)	184	.64	3.6	11.1	17.0	16	30
9889	Monroe.....	Monroe.....	Dolomite.....	11, 750	175	3.03	4.2	9.5	(1)	5	23
9888	do.....	do.....	Argillaceous dolomite.....	(1)	165	1.47	4.7	8.5	13.5	5	22
9989	do.....	do.....	do.....	(1)	175	1.80	3.6	11.1	17.0	17	27
10041	do.....	do.....	Dolomite.....	(1)	172	2.82	12.4	3.2	17.0	17	18
9888	Sibley.....	Wayne.....	Limestone.....	(1)	159				15.3	6	44

MINNESOTA.

10455	Jasper.....	Rock.....	Quartzite.....	(1)	164	0.18	2.0	20.0	19.7	17	(1)
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MISSISSIPPI.

10287	(2).....	Holmes.....	Sandstone.....	(1)	144	4.70	7.8	5.1	18.0	8	(1)
10098	New Albany.....	Union.....	do.....	(1)	156	2.58	7.1	3.6	18.7	7	5

¹ Test not made.² Exact locality not known.

TABLE I.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, from Jan. 1, 1916, to Jan. 1, 1917—Con.

MISSOURI.

Serial No.	Town or city.	County.	Name of material.	Crushing strength, pounds per square inch.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
10169	West Line.....	Cass.....	Limestone.....	(1)	Pounds. 136	Pounds. 1.09	11.5	3.5	13.5	5	24
10410	(1).....	do.....	do.....	(1)*	167	.53	8.6	7.2	14.7	6	31
10251	Hamburg.....	St. Charles.....	do.....	(1)	167	.63	5.2	7.1	12.3	4	37
10252	do.....	do.....	do.....	(1)	164	.90	7.3	3.5	10.7	3	34
10237	Sinclair.....	do.....	do.....	(1)	167	.73	4.0	10.0	16.0	7	25
10238	do.....	do.....	do.....	(1)	167	.75	5.1	7.9	15.3	5	22

NEBRASKA.

99405	Nehawka.....	Cass.....	Argillaceous limestone.....	(1)	108	0.75	4.7	8.5	16.0	6	42
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NEW HAMPSHIRE.

9946	Fitzwilliam.....	Cheshire.....	Granite.....	26,100	165	0.32	3.7	10.8	17.7	9	15
9893	Marlboro.....	do.....	do.....	15,615	165	.36	6.7	6.0	17.3	8	18
9894	do.....	do.....	do.....	15,255	165	.52	5.7	7.0	19.3	6	23
9895	Fitzwilliam.....	do.....	do.....	10,825	165	.33	3.8	10.5	18.7	9	17
9994	Allenstown.....	Merrimack.....	do.....	18,110	165	.61	2.5	16.0	19.0	11	23

NEW JERSEY.

10795	Lambertville.....	Hunterdon.....	Diabase.....	(1)	133	0.46	2.8	14.3	18.7	19	49
9921	Mount Hope.....	Morris.....	Pyroxene granite.....	(1)	178	.44	2.4	16.7	17.8	9	18
10472	Boundbrook.....	Somerset.....	Altered diabase.....	(1)	184	.06	2.2	18.2	18.7	30	54

NEW MEXICO.

9768	Silver City.....	Grant.....	Altered granite porphyry.....	(1)	156	1.73	3.4	11.8	18.6	18.	(1)
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NEW YORK.

10097	Dolgeville.....	Herkimer.....	Dolomite.....	(1)	173	0.66	3.1	12.9	15.3	10	29
10236	Alexandria Bay.....	Jefferson.....	Biotite granite.....	(1)	163	.49	(1)	(1)	18.7	12	12
10319	do.....	do.....	Granite.....	28,900	(1)	(1)	2.8	14.3	18.0	10	(1)
10042	Albion.....	Orleans.....	Sandstone.....	20,000	(1)	(1)	3.4	11.8	17.3	9	(1)
10093	Rockland Lake.....	Rockland.....	Gabbroitic diabase.....	(1)	187	.19	3.0	13.3	19.0	13	29
10094	do.....	do.....	do.....	(1)	183	.27	3.6	11.1	19.0	12	67
10771	do.....	do.....	do.....	(1)	189	.28	3.0	13.3	18.7	19	37
10191	Hopkinton.....	St. Lawrence.....	Sandstone.....	(1)	157	2.02	2.8	14.3	18.0	12	7
11181	Tusten.....	Sullivan.....	Feldspathic sandstone.....	26,300	171	.64	3.0	12.1	15.3	14	(1)
11182	Collicum.....	do.....	do.....	22,620	166	1.04	3.0	13.3	14.7	13	(1)
10089	Peekskill (south of).....	Westchester.....	Hypersthene syenite.....	(1)	179	.62	3.5	11.4	17.0	9	(1)
11199	Yorktown.....	do.....	Granite.....	16,200	168	.77	5.8	6.9	18.0	5	(1)

NORTH CAROLINA.

10193	Cranberry.....	Avery.....	Hornblende gneiss.....	(1)	208	0.70	4.3	9.3	(1)	(1)	18
10194	do.....	do.....	do.....	(1)	192	.48	5.5	7.3	(1)	7	16
9858	Asheville.....	Buncombe.....	Biotite gneiss.....	(1)	168	.26	4.4	9.1	19.3	(1)	33
10972	do.....	do.....	do.....	(1)	168	1.35	2.7	14.8	18.0	10	(1)
10973	do.....	do.....	do.....	(1)	172	.67	3.7	11.4	18.0	(1)	(1)
9892	Granite Quarry.....	Rowan.....	Granite.....	21,125	(1)	(1)	4.6	8.7	(1)	(1)	(1)
10306	Granite Quarry (near).....	do.....	do.....	34,860	164	.22	2.0	20.0	18.7	11	(1)
10405	do.....	do.....	do.....	(1)	(1)	(1)	(1)	(1)	(1)	10	(1)
10412	do.....	do.....	do.....	20,930	164	.51	2.8	14.3	19.3	9	(1)
10413	do.....	do.....	do.....	23,580	162	.43	3.3	12.1	19.0	7	(1)
10770	do.....	do.....	do.....	(1)	164	.43	5.2	7.7	19.3	10	(1)
9897	do.....	(2)	do.....	(1)	162	.55	13.8	2.9	(1)	(1)	14

OHIO.

9864	Lima.....	Allen.....	Dolomite.....	(1)	165	2.67	3.2	12.5	14.7	7	(1)
0025	do.....	do.....	Argillaceous limestone.....	(1)	168	2.77	3.5	11.4	14.7	12	31
0026	do.....	do.....	do.....	(1)	168	1.96	3.7	10.8	16.0	11	33
0027	do.....	do.....	do.....	(1)	168	2.26	3.6	11.1	15.0	11	34
0305	do.....	do.....	Limestone.....	(1)	169	1.80	4.2	9.5	16.0	6	27
9953	Middletown.....	Butler.....	Basic open-hearth slag.....	(1)	209	2.33	4.1	9.8	(1)	(1)	471
9954	do.....	do.....	do.....	(1)	190	2.74	20.4	1.7	(1)	(1)	191

¹ Test not made.² Exact locality not known.

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Serial No.	Town or city.	County.	Name of material.	Crushing strength, per pounds per square inch.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
10516	Farmer.....	Clinton.....	Limestone.....	(1)	Pounds, 171	1.66	5.2	7.6	13.2	4	36
10517	do.....	do.....	Siliceous limestone.....	(1)	167	.49	6.6	6.1	13.7	5	45
10536	Marble Cliff.....	Franklin.....	Argillaceous limestone.....	(1)	(1)	(1)	(1)	(1)	15.2	6	27
9883	North Baltimore (Wood County, near).	Henry.....	Argillaceous dolomite.....	(1)	168	2.61	5.0	8.0	16.0	10	44
11198	Bellevue.....	Huron.....	Dolomite.....	(1)	156	4.89	4.9	8.2	6.0	5	52
9854	Ironton.....	Lawrence.....	Blast-furnace slag.....	(1)	181	.73	3.3	6.9	16.0	6	21
9860	Waterville.....	Lucas.....	Argillaceous dolomite.....	(1)	168	2.36	3.3	12.1	16.3	11	47
9983	do.....	do.....	Dolomite.....	(1)	168	2.04	2.8	14.3	16.3	14	38
11097	White House.....	do.....	Siliceous limestone.....	(1)	161	2.90	6.2	6.5	9.3	6	41
10537	Piqua.....	Miami.....	Dolomite.....	(1)	156	2.53	10.3	3.9	11.0	4	35
10538	do.....	do.....	do.....	(1)	178	.97	4.8	8.3	15.0	13	30
10532	Centerville.....	Montgomery.....	Argillaceous limestone.....	(1)	(1)	(1)	(1)	(1)	(1)	3	30
10533	do.....	do.....	do.....	(1)	(1)	(1)	(1)	(1)	(1)	5	24
10535	do.....	do.....	do.....	(1)	(1)	(1)	(1)	(1)	(1)	3	37
9945	Rocky Ridge.....	Ottawa.....	Dolomite.....	13,360	175	.41	5.4	7.4	12.0	9	37
9973	Limestone.....	do.....	do.....	(1)	162	(1)	5.5	7.3	12.0	7	38
10539	New Paris.....	Preble.....	do.....	(1)	167	1.12	3.4	11.8	16.2	6	37
10346	Luckey.....	Wood.....	do.....	(1)	162	3.68	7.3	5.5	16.2	6	38
9947	Bowling Green.....	do.....	do.....	(1)	165	1.38	7.5	5.3	12.2	6	33
9957	North Baltimore.....	do.....	do.....	(1)	168	2.08	4.0	10.0	14.3	14	50
PENNSYLVANIA.											
9786	Granite.....	Adams.....	Gabbroitic diabase.....	23,435	(1)	(1)	(1)	(1)	15.2	14	(1)
10104	Birdsboro (near).	Berks.....	Diabase.....	(1)	(1)	(1)	1.7	23.5	18.7	13	(1)
10357	do.....	Delaware.....	Biotite gneiss.....	(1)	(1)	(1)	(1)	(1)	18.0	9	(1)
9773	Connellsville.....	Payette.....	Siliceous limestone.....	(1)	168	0.46	2.8	14.3	17.7	13	85
10518	Montoursville.....	Lycening.....	Argillaceous limestone.....	23,460	168	.10	6.6	16.1	16.2	6	27
10672	Jersey Shore.....	do.....	Siliceous limestone.....	(1)	166	.44	2.6	15.4	18.2	9	53
10137	South Bethlehem.....	Northampton.....	Argillaceous limestone.....	(1)	165	4.42	3.3	12.1	13.7	3	103
10429	Mount Carmel.....	Northumberland.....	Quartzite.....	(1)	163	.53	3.3	12.1	19.0	13	(1)
9812	Holmesburg.....	Philadelphia.....	Biotite gneiss.....	(1)	165	.58	(1)	(1)	19.0	17	(1)
11190	Shohola.....	Pike.....	Feldspathic sandstone.....	25,250	170	.63	3.2	12.5	16.7	12	(1)
10345	Confluence.....	Somerset.....	Calcareous sandstone.....	24,790	168	.34	3.6	11.1	16.7	7	(1)

RHODE ISLAND.

10171	Lincoln.....	Providence.....	Granite gneiss.....	(1)	170	0.17	3.9	10.3	18.7	12	20
10248	East Providence.....	do.....	Feldspathic sandstone.....	(1)	168	.59	3.6	11.1	18.0	12	16
10467	Westerly.....	Washington.....	Granite.....	(1)	161	.37	3.9	10.3	18.7	9	(1)

SOUTH CAROLINA.

10531	Rion.....	Fairfield.....	Biotite granite.....	(1)	165	0.59	4.4	9.1	18.3	8	(1)
10131	Greenville (17 miles from).....	Greenville.....	Granite.....	(1)	165	.82	4.4	9.1	18.7	8	18
10129	Greenville.....	do.....	Hornblende gneiss.....	(1)	172	.68	8.0	5.0	17.0	6	20
10130	Beverly.....	Pickens.....	Biotite gneiss.....	(1)	166	.75	4.1	9.8	17.7	4	

SOUTH DAKOTA.

10108	Dell Rapids.....	Minnehaha.....	Quartzite.....	(1)	165	0.41	2.8	14.3	19.3	17	5
10894	Stout Falls.....	do.....	do.....	(1)	163	.27	1.4	28.6	19.3	17	(1)
10895	do.....	do.....	Olivine diabase.....	(1)	190	.37	2.7	14.8	18.7	18	16
10896	Rowena.....	do.....	Quartzite.....	(1)	164	.28	2.7	14.8	19.3	17	(1)

TENNESSEE.

9992	Maryville.....	Blount.....	Argillaceous limestone.....	(1)	168	0.40	3.8	10.5	16.7	6	49
9993	do.....	do.....	Limestone.....	(1)	168	.30	4.3	9.3	15.7	5	39
10292	New Tazewell.....	Claborn.....	Siliceous limestone.....	(1)	171	1.84	4.2	9.5	13.3	8	31
10326	Harrigate (near).....	do.....	Dolomite.....	(1)	174	.92	3.2	12.5	16.0	14	19
10327	Harrigate.....	do.....	do.....	(1)	171	1.83	3.6	11.1	13.3	7	21
10446	New Tazewell (near).....	do.....	do.....	(1)	172	1.20	4.1	9.8	15.3	9	42
10581	New Tazewell.....	do.....	Siliceous dolomite.....	(1)	170	1.93	4.1	9.8	15.2	9	18
10483	Jamestown.....	Fentress.....	Sandstone.....	(1)	145	3.97	10.8	3.7	15.0	4	
9887	Mascot.....	Knox.....	Dolomite.....	(1)	178	.20	4.1	9.8	16.0	11	(1)
10315	Madisonville.....	Monroe.....	Ferruginous sandstone.....	(1)	178	.41	4.0	10.0	17.3	8	49
10316	do.....	do.....	Siliceous limestone.....	(1)	169	.46	6.3	6.4	16.7	9	29
10317	do.....	do.....	Limestone.....	(1)	167	.77	8.3	4.8	16.7	9	33
10318	do.....	do.....	do.....	(1)	171	.33	4.2	9.5	17.3	8	26
10323	do.....	do.....	Crystalline limestone.....	(1)	165	.33	6.0	6.6	13.3	5	49
10414	(1).....	do.....	Siliceous dolomite.....	(1)	174	1.36	3.3	12.1	15.7	18	29
9734	(2).....	Pickett.....	Argillaceous dolomite.....	(1)	168	2.65	4.3	9.3	13.2	12	55

1 Test not made.

2 Exact locality not known.

TABLE I.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, from Jan. 1, 1916, to Jan. 1, 1917.—Con.
TEXAS.

Serial No.	Town or city.	County.	Name of material.	Crushing strength, pounds per square inch.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
10044	(¹)	Grayson.	Clay limestone.	(¹)	Pounds. 134	Pounds. 12.80	(¹)	(¹)	0.0	2	(¹)
VERMONT.											
10848	Burlington.	Chittenden.	Siliceous dolomite.	(¹)	163	0.26	3.7	11.1	16.7	13	38
11191	Derby.	Orleans.	Siliceous limestone.	(¹)	171	.46	3.0	13.3	17.3	9	96
9673	Barre.	Washington.	Biotite granite.	(¹)	165	.37	2.8	14.3	19.0	9	19
VIRGINIA.											
9928	(¹)	Albemarle.	Biotite gneiss.	(¹)	175	1.62	5.3	7.5	17.6	7	36
9927	(¹)	do.	Hornblende gneiss.	(¹)	193	.98	3.5	11.4	16.3	9	47
9926	(¹)	do.	Biotite gneiss.	(¹)	181	.57	5.1	7.8	18.7	7	63
10253	Charlottesville.	do.	Granite gneiss.	(¹)	171	.75	5.4	7.4	17.3	5	24
10172	Clifton Forge.	Alleghany.	Siliceous limestone.	(¹)	166	.48	2.5	16.0	(¹)	10	48
9891	Lone Jack Station.	Campbell.	Quartzite schist.	(¹)	159	1.34	12.0	3.3	(¹)	(¹)	8
9904	do.	do.	Aplitic granite.	(¹)	165	.53	5.4	7.4	18.7	7	5
10344	Lynchburg.	do.	Quartzite.	25,885	160	1.20	4.3	9.3	18.6	14	(¹)
9819	Cliff View.	Carroll.	Hornblende schist.	(¹)	184	.71	4.4	9.1	18.3	14	31
9820	do.	do.	Altered hornblende gneiss.	(¹)	181	1.60	15.8	2.5	14.3	5	109
10115	Boston.	Culpeper.	Altered rhyolite.	(¹)	168	.84	4.7	8.5	19.0	5	(¹)
9919	Warrenton.	Fauquier.	Amphibolite.	(¹)	187	.76	4.6	8.7	(¹)	(¹)	44
9920	do.	do.	do.	(¹)	181	2.44	5.9	6.7	(¹)	(¹)	120
9870	do.	do.	Epidote chlorite schist.	(¹)	187	1.46	3.6	11.1	(¹)	(¹)	43
10304	do.	do.	do.	(¹)	185	.63	3.5	11.4	14.7	11	(¹)
10099	Hamilton (¼ mile east of).	Loudoun.	Amphibolite.	(¹)	178	.49	3.9	10.3	17.3	10	17
10098	Luray.	Page.	Argillaceous limestone.	(¹)	167	.75	5.4	7.4	14.3	5	27
10298	Buckland.	Prince William.	Diabase.	(¹)	178	1.75	(¹)	(¹)	17.3	(¹)	35
10630	Gate.	Scott.	Argillaceous limestone.	(¹)	168	.38	4.1	9.7	16.0	13	35
10780	Wise.	Wise.	Sandstone.	(¹)	158	2.10	4.5	8.8	18.7	10	(¹)

WASHINGTON.

10239	Cook (3 miles north of).....	Skamania.....	Basalt.....	(1)	177	0.92	2.6	15.4	18.3	24	14
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WEST VIRGINIA.

10064	Martinsburg (south of).....	Berkeley.....	Dolomite.....	(1)	178	0.31	3.6	11.1	16.3	10	29
10069	Butts Store.....	do.....	Feldspathic sandstone.....	(1)	140	3.45	7.2	5.6	18.7	(1)	8
10073	Hedgesville (west of).....	do.....	do.....	(1)	165	.62	2.8	14.3	16.7	(1)	61
10087	Tomahawk (north of).....	do.....	Sandstone.....	(1)	156	1.66	7.9	5.1	(1)	(1)	23
10062	Inwood (near).....	do.....	do.....	(1)	144	3.19	16.6	2.4	19.3	2	17
10063	Ferri Ridge.....	do.....	Limestone.....	(1)	168	1.61	6.2	6.5	14.0	4	56
10065	Blairton (near).....	do.....	Argillaceous limestone.....	(1)	168	.19	5.1	7.8	16.7	6	28
10066	Berkeley Station.....	do.....	Limestone.....	(1)	168	.27	6.3	6.4	16.0	4	34
10067	Jones Spring.....	do.....	Siliceous limestone.....	(1)	168	.31	4.4	9.1	17.3	9	44
10068	Bedington (east of).....	do.....	Argillaceous limestone.....	(1)	172	.19	4.9	8.2	16.0	10	33
10070	Bunker Hill.....	do.....	Limestone.....	(1)	168	.24	5.1	7.8	16.0	4	34
10071	Nipetown.....	do.....	do.....	(1)	168	.43	4.9	8.2	16.0	3	32
10072	Spring Mills.....	do.....	do.....	(1)	168	.27	4.2	9.5	15.0	4	45
10074	Gerrardstown.....	do.....	Argillaceous limestone.....	(1)	172	.46	6.5	6.2	15.7	(1)	22
10075	Bedington (east of).....	do.....	do.....	(1)	168	.32	5.6	7.1	(1)	(1)	29
10076	Van Clevessville (south of).....	do.....	Limestone.....	(1)	168	.36	5.0	8.0	17.0	9	(1)
10077	Darksesville.....	do.....	Siliceous limestone.....	(1)	168	.31	5.0	8.0	15.0	4	33
10078	Tomahawk.....	do.....	Limestone.....	(1)	168	.27	4.5	8.9	18.3	15	47
10079	Falling Water.....	do.....	Argillaceous limestone.....	(1)	168	1.27	4.7	8.5	16.7	8	20
10080	Little Georgetown.....	do.....	Crystalline limestone.....	(1)	175	.37	6.5	6.2	18.7	10	24
10081	Jones Spring.....	do.....	Limestone.....	(1)	168	.37	5.7	7.0	14.0	4	47
10082	Falling Water (near).....	do.....	Chert and limestone (mixed).....	(1)	168	.59	5.6	7.1	(1)	(1)	25
10083	Falling Water.....	do.....	Limestone.....	(1)	(1)	(1)	4.7	8.5	(1)	(1)	23
10084	Blairton.....	do.....	Limestone.....	(1)	168	.23	5.9	6.8	16.3	5	20
10085	Cumbo.....	do.....	do.....	(1)	172	.52	4.6	8.7	16.7	4	32
10086	Martinsburg (south of).....	do.....	do.....	(1)	168	.56	5.8	6.9	18.0	5	39
10102	Martinsburg.....	do.....	do.....	(1)	168	(1)	5.2	7.7	16.7	6	(1)
10511	Scherr.....	do.....	Argillaceous limestone.....	(1)	166	.60	5.4	7.4	(1)	(1)	31
9925	Renick.....	do.....	do.....	(1)	168	.66	3.8	10.5	16.3	8	41
9972	Fort Spring.....	do.....	Limestone.....	(1)	168	.24	4.1	9.8	15.7	9	57
16103	Kearneyville.....	do.....	do.....	(1)	(1)	(1)	2.7	14.8	14.0	6	(1)
9966	Greer.....	do.....	Argillaceous limestone.....	(1)	168	.73	4.7	8.5	15.7	8	40
9967	do.....	do.....	do.....	(1)	168	.59	4.7	8.5	15.7	9	63
9968	do.....	do.....	do.....	(1)	168	.73	4.8	8.3	14.0	9	37
9969	do.....	do.....	Siliceous limestone.....	(1)	168	.56	3.0	13.3	16.7	10	47
10348	Albright (near).....	do.....	Sandstone.....	(1)	154	1.88	8.1	4.9	17.3	5	(1)
10349	Albright.....	do.....	Ferruginous sandstone.....	(1)	160	2.40	4.0	10.0	15.3	9	(1)
11130	Trap Hill District.....	Raleigh.....	Sandstone.....	(1)	154	3.69	3.9	10.3	16.6	4	(1)
10036	Spencer (near).....	do.....	Feldspathic sandstone.....	(1)	156	3.52	12.3	3.3	8.7	8	32
10509	Davis.....	Tucker.....	Siliceous limestone.....	(1)	167	.05	3.7	10.8	14.3	10	30
10510	do.....	do.....	Argillaceous limestone.....	(1)	168	.12	5.0	8.0	16.3	6	37

1 Test not made.

2 Exact locality not known.

TABLE I.—Results of physical tests of road-building rocks from the United States, Canada, Porto Rico, and Cuba, from Jan. 1, 1916, to Jan. 1, 1917—Con.

WISCONSIN.

Serial No.	Town or city.	County.	Name of material.	Crushing strength, pounds per square inch.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
9999	Berlin.....	Green Lake.....	Rhyolite.....	(1)	Pounds. 165	0.16	1.9	21.3	19.0	25	15
10168	Rufalo.....	Marquette.....	Altered syenite.....	(1)	167	0.13	2.2	18.2	19.3	30	13
10014	Wauwatosa.....	Milwaukee.....	Argillaceous dolomite.....	(1)	168	2.11	3.7	12.5	14.7	8	(1) 62
11123	do.....	do.....	do.....	16,700	168	2.01	3.8	10.5	13.3	11	(1)
10986	Wells.....	Monroe.....	Calcareous sandstone.....	(1)	162	2.79	4.8	8.3	18.0	5	31
9970	Black Creek.....	Outagamie.....	Dolomite.....	(1)	178	.58	4.6	8.7	14.7	9	31
9971	do.....	do.....	do.....	(1)	178	.53	4.1	9.8	15.3	8	30
10022	Belgium.....	Ozaukee.....	Argillaceous dolomite.....	(1)	175	1.15	7.4	5.5	14.3	5	3
10159	Grand Rapids.....	Wood.....	Sandstone.....	(1)	153	1.91	3.3	12.1	18.3	5	3
10028	(?).....	(?).....	Dolomite.....	(1)	168	1.05	7.1	5.6	13.3	6	41

CANADA.

10017	Montreal.....	Province of Quebec.....	Nephelite syenite.....	(1)	156	0.60	2.2	18.2	18.7	18	22
10352	Wellesley Island.....	do.....	Biotite granite.....	(1)	165	.28	2.9	13.8	18.0	10	(1)
9746	Welland.....	Province of Ontario.....	Cherty limestone.....	(1)	165	.41	3.9	10.3	18.3	13	82

¹ Test not made.² Exact locality not known.

TABLE II.—Results of compression tests of rock complete to January 1, 1917.

ARKANSAS.				
Serial No.	Locality.	County.	Name.	Crushing strength, pounds per square inch.
9828	Lamar.....	Johnson.....	Feldspathic sandstone.....	21,980
6331	Bald Knob.....	White.....	Sandstone.....	19,860
CONNECTICUT.				
9791	Oneco.....	Windham.....	Biotite granite.....	16,635
11098	do.....	do.....	do.....	23,290
11099	do.....	do.....	Gneissoid granite.....	20,200
GEORGIA.				
10381	Southeast side Kennesaw Mountain.....	Cobb.....	Feldspathic gneiss.....	18,500
10382	Marietta, 4 miles southwest of.....	do.....	Biotite gneiss.....	14,000
10389	Austell, $\frac{3}{4}$ mile west.....	do.....	Granite gneiss.....	12,890
10393	Blackwell Station, 1 mile north of.....	do.....	Hornblende gneiss.....	17,350
ILLINOIS.				
4422	Embarras.....	Coles.....	Limestone.....	17,300
5509	Thornton.....	Cook.....	Dolomite.....	23,060
6053	do.....	do.....	do.....	16,880
8711	Hillside.....	do.....	Argillaceous dolomite.....	15,730
4660	Tunnell Hill.....	Johnson.....	Sandstone.....	19,150
7509	Reevesville.....	do.....	Argillaceous limestone.....	25,780
7510	do.....	do.....	do.....	28,400
4764	Kankakee.....	Kankakee.....	Dolomite.....	20,610
5550	do.....	do.....	do.....	17,710
6088	do.....	do.....	Argillaceous dolomite.....	20,830
6165	do.....	do.....	Dolomite.....	11,660
6865	do.....	do.....	do.....	13,500
7298	do.....	do.....	Argillaceous dolomite.....	25,850
7299	do.....	do.....	do.....	20,000
7300	do.....	do.....	do.....	19,800
7301	do.....	do.....	do.....	19,700
7302	do.....	do.....	Dolomite.....	17,050
7871	Lehigh.....	do.....	Argillaceous dolomite.....	16,700
10367	Kankakee.....	do.....	Dolomite.....	11,180
4421	Alton.....	Madison.....	Limestone.....	15,100
7422	Brookville.....	Ogle.....	Argillaceous dolomite.....	18,640
7423	do.....	do.....	do.....	18,180
5549	Anna.....	Union.....	Limestone.....	19,510
9827	Joliet.....	Will.....	Dolomite.....	8,130
INDIANA.				
5534	Logansport.....	Cass.....	Limestone.....	20,350
4655	Greensburg.....	Decatur.....	Dolomite.....	17,960
4658	St. Paul.....	do.....	Limestone.....	18,400
4659	do.....	do.....	Dolomitic limestone.....	20,510
4690	Westport.....	do.....	do.....	20,000
5088	St. Paul.....	do.....	Limestone.....	19,800
11183	Huntington.....	Huntington.....	Dolomite.....	25,420
4197	Mitchell.....	Lawrence.....	Argillaceous dolomite.....	12,250
5027	Bedford.....	do.....	Limestone.....	6,900
5029	do.....	do.....	do.....	6,450
3368	Greencastle.....	Putnam.....	do.....	16,000
5737	Osgood.....	Ripley.....	do.....	14,470
4657	Wabash.....	Wabash.....	Dolomitic limestone.....	18,790

TABLE II.—Results of compression tests of rock complete to Jun. 1, 1917—Continued.

IOWA.				
Serial No.	Locality.	County.	Name.	Crushing strength, pounds per square inch.
5525	Cedar Rapids.....	Linn.....	Dolomitic limestone.....	19,950
5526	La Grande.....	Marshall.....	do.....	14,850
KANSAS.				
9599	Fort Scott (7 miles west).....	Bourbon.....	Limestone breccia.....	7,380
KENTUCKY.				
5552	Princeton.....	Caldwell.....	Dolomitic limestone.....	23,860
7688	Cedar Bluff.....	do.....	Argillaceous limestone.....	25,720
5921	Limestone.....	Carter.....	Limestone.....	14,900
5922	Carter.....	do.....	Siliceous limestone.....	13,400
MAINE.				
10219	North Jay.....	Franklin.....	Granite.....	21,260
7438	Swan's Island.....	Hancock.....	Biotite granite.....	18,400
9997	Somes Sound, Mount Desert Islands.....	do.....	Granite.....	19,780
10233	do.....	do.....	do.....	19,220
10234	do.....	do.....	do.....	24,700
10988	Ship Harbor.....	do.....	do.....	28,650
10989	do.....	do.....	do.....	26,500
10990	do.....	do.....	do.....	32,450
8745	Vinal Haven.....	Knox.....	do.....	20,020
8768	St. George.....	do.....	do.....	22,800
8769	Vinal Haven.....	do.....	do.....	20,920
9781	St. George.....	do.....	do.....	18,780
9865	do.....	do.....	do.....	17,150
9996	Long Cove.....	do.....	do.....	17,540
9445	Vinal Haven.....	do.....	Biotite granite.....	21,220
10249	Long Cove.....	do.....	do.....	22,500
10250	do.....	do.....	Granite.....	22,330
10366	St. George.....	do.....	do.....	27,050
10019	Vinal Haven.....	do.....	Biotite granite.....	21,650
7439	Frankford.....	Waldo.....	do.....	20,600
, MARYLAND.				
5611	Mount Savage Junction.....	Allegany.....	Siliceous limestone.....	34,920
4884	Frederick.....	Frederick.....	Limestone.....	17,580
5694	Have de Grace.....	Harford.....	Gneissoid granite.....	34,410
5695	do.....	do.....	Sericite gneiss.....	20,090
5696	do.....	do.....	Gneissoid granite.....	21,670
5697	do.....	do.....	Amphibolite.....	34,380
5698	do.....	do.....	Gneissoid granite.....	35,210
5699	do.....	do.....	do.....	22,190
MASSACHUSETTS.				
10288	Otis.....	Berkshire.....	Granite.....	18,260
6891	Rockport.....	Essex.....	Biotite granite.....	22,370
6892	do.....	do.....	do.....	23,610
6893	do.....	do.....	do.....	22,670
6894	do.....	do.....	do.....	21,600
8796	do.....	do.....	do.....	23,830
9649	Gloucester.....	do.....	Granite.....	19,580
9650	do.....	do.....	do.....	18,130
9651	Rockport.....	do.....	do.....	22,390
9652	do.....	do.....	do.....	18,780
5671	Westfield.....	Hampden.....	Altered diabase.....	32,850

TABLE II.—Results of compression tests of rock complete to Jan. 1, 1917—Continued.

MASSACHUSETTS—Continued.

Serial No.	Locality.	County.	Name.	Crushing strength, pounds per square inch.
8862	Westford.....	Middlesex.....	Granite.....	13,980
8874	do.....	do.....	do.....	17,000
8875	do.....	do.....	do.....	16,250
5988	West Auburn.....	Worcester.....	Mica gneiss.....	21,950

MICHIGAN.

9988	Monroe.....	Monroe.....	Argillaceous dolomite.....	11,750
5953	Calcite.....	Presque Isle.....	Limestone.....	10,300

MINNESOTA.

5524	Stockton.....	Winona.....	Argillaceous dolomite.....	16,000
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MISSOURI.

6375	Rocheport.....	Boone.....	Limestone.....	13,900
10169	West Line.....	Cass.....	do.....	16,690
6377	Sweeney.....	Cooper.....	Argillaceous limestone.....	14,900

NEW YORK.

6457	(1).....	Clinton.....	Plagioclase gneiss.....	18,500
6458	(1).....	do.....	Pyroxene gneiss.....	20,500
8011	(1).....	Dutchess.....	Dolomite.....	34,450
5544	Camelo.....	do.....	do.....	29,050
5872	Akron Junction.....	Erie.....	Cherty limestone.....	16,700
8577	Gloversville.....	Fulton.....	Biotite gneiss.....	14,585
4157	Alexandria Bay.....	Jefferson.....	Granite.....	21,600
8833	do.....	do.....	do.....	26,180
8902	do.....	do.....	do.....	14,150
9129	do.....	do.....	do.....	14,390
9130	do.....	do.....	Gneissoid granite.....	17,600
7437	do.....	do.....	Granite.....	27,200
10236	do.....	do.....	Biotite granite.....	28,130
10042	Albion.....	Orleans.....	Sandstone.....	29,000
8012	(1).....	Rockland.....	Gabbroitic diabase.....	31,300
8013	(1).....	do.....	Siliceous dolomite.....	22,200
10191	Hopkinton.....	St. Lawrence.....	Sandstone.....	35,240
11182	Callicoon.....	Sullivan.....	Feldspathic sandstone.....	22,620
11181	Tusten.....	do.....	do.....	26,300
11199	Yorktown.....	Westchester.....	Granite.....	16,200

NEW HAMPSHIRE.

9893	Marlboro.....	Cheshire.....	Granite.....	15,615
9894	do.....	do.....	do.....	15,250
9895	Fitzwilliam.....	do.....	do.....	10,830
9946	(1).....	do.....	do.....	26,100
8872	Melford.....	Hillsboro.....	do.....	15,050
9010	do.....	do.....	Biotite granite.....	16,640
9011	do.....	do.....	do.....	14,870
9012	do.....	do.....	do.....	18,230
9031	Concord.....	Merrimack.....	Granite.....	16,600
9036	do.....	do.....	do.....	13,420
9037	do.....	do.....	do.....	13,900
8870	do.....	do.....	do.....	15,100
9994	Allentown.....	do.....	do.....	18,110

¹ Exact locality not known.

TABLE II.—Results of compression tests of rock complete to Jan. 1, 1917—Continued.

NORTH CAROLINA.

Serial No.	Locality.	County.	Name.	Crushing strength, pounds per square inch.
8396	(1).....	Forsythe.....	Granite.....	13, 140
8397	(1).....	do.....	Hypersthene gabbro.....	11, 880
8682	Spencer Mountain.....	Gaston.....	Feldspathic quartzite.....	31, 520
8881	Gastonia.....	do.....	Quartzite.....	17, 100
8576	Mooresville.....	Iredell.....	Biotite granite.....	26, 000
5373	(1).....	McDowell.....	Sandstone.....	22, 600
9038	Wilson.....	Wilson.....	Granite.....	16, 070
5956	Stacey.....	Rockingham.....	Granite gneiss.....	23, 220
5496	Sansbury.....	Rowan.....	Granite.....	33, 750
9892	Granite Quarry.....	do.....	do.....	21, 130
10306	Granite Quarry (near).....	do.....	do.....	34, 860
10412	(1).....	do.....	do.....	20, 930
10413	(1).....	do.....	do.....	23, 580
10770	(1).....	do.....	do.....	17, 800
11200	(1).....	do.....	do.....	26, 400
6071	Bostic.....	Rutherford.....	Biotite gneiss.....	16, 100
5497	Mount Airy.....	Surry.....	Granite.....	18, 400
7433	do.....	do.....	do.....	15, 200
8901	do.....	do.....	do.....	5, 100
9048	do.....	do.....	do.....	16, 440
8419	Granita (near).....	Wake.....	Biotite granite.....	14, 160
3807	Wise.....	Warren.....	Granite.....	18, 240
3808	do.....	do.....	do.....	18, 560
5374	(1).....	Yancey.....	Quartzite.....	12, 900

OHIO.

4694	Osborne.....	Clarke.....	Dolomitic limestone.....	8, 690
4695	Springfield.....	do.....	Dolomite.....	18, 960
9282	Cleveland.....	Cuyahoga.....	Granite.....	31, 790
9283	do.....	do.....	do.....	27, 900
9284	do.....	do.....	do.....	24, 790
9285	do.....	do.....	do.....	26, 990
9459	do.....	do.....	do.....	24, 900
4378	Sandusky.....	Erie.....	Limestone.....	19, 400
5554	do.....	do.....	do.....	21, 850
5753	Castalia.....	do.....	Dolomitic limestone.....	18, 530
6055	do.....	do.....	Limestone.....	20, 810
6056	Akron Junction.....	do.....	Cherty limestone.....	31, 180
5505	Marble Cliff.....	Fran'lin.....	Limestone.....	16, 750
5506	do.....	do.....	do.....	12, 350
5630	Columbus.....	do.....	Ferruginous sandstone.....	21, 800
4693	Patterson.....	Hardin.....	Dolomite.....	11, 360
5553	Dunkirk.....	do.....	do.....	23, 200
4707	Hillsboro.....	Highland.....	Cherty limestone.....	15, 590
8347	Clarksfield.....	Huron.....	Calcareous sandstone.....	9, 490
4656	Big Springs.....	Logan.....	Argillaceous limestone.....	16, 380
6054	Vulcan.....	Lucas.....	Siliceous limestone.....	25, 480
6057	Holland.....	do.....	Argillaceous limestone.....	19, 430
8402	Toledo, 10 miles west of.....	do.....	Dolomite.....	11, 600
10537	Piqua.....	Miami.....	do.....	9, 810
10538	do.....	do.....	do.....	15, 150
6052	White Rock.....	Ottawa.....	do.....	16, 620
9445	Rocky Ridge.....	do.....	do.....	13, 300
10539	New Paris.....	Preble.....	do.....	16, 480
5556	Bloomville.....	Seneca.....	Limestone.....	20, 250
5555	Middleport.....	Van Wert.....	Dolomite.....	25, 200

OKLAHOMA.

3388	Granite.....	Greer.....	Granite.....	18, 000
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PENNSYLVANIA.

9786	Granite.....	Adams.....	Gabbroitic diabase.....	23, 440
5602	Hyndman.....	Bedford.....	Impure limestone.....	24, 150
5603	do.....	do.....	Siliceous limestone.....	21, 860
5632	Birdsboro.....	Berks.....	Altered diabase.....	39, 215

¹ Exact locality not known.

TABLE II.—Results of compression tests of rock complete to Jan. 1, 1917—Continued.

PENNSYLVANIA—Continued.

Serial No.	Locality.	County.	Name.	Crushing strength, pounds per square inch.
8724	Juniata.....	Blair.....	Argillaceous limestone.....	15, 480
8725	(1).....	do.....	do.....	20, 880
8625	Hazard.....	Carbon.....	Blast-furnace slag.....	9, 000
7973	(1).....	Chester.....	Pyroxene quartzite.....	31, 800
7978	(1).....	do.....	Mica schist.....	23, 500
7979	(1).....	do.....	do.....	23, 900
5578	Salona.....	Clinton.....	Argillaceous limestone.....	18, 710
7844	(1).....	Dauphin.....	Siliceous limestone.....	26, 500
8306	(1).....	do.....	Limestone.....	8, 510
8427	(1).....	do.....	do.....	19, 250
8465	(1).....	do.....	Siliceous dolomite.....	9, 640
8049	(1).....	Elk.....	Ferruginous sandstone.....	14, 150
5771	Indian Creek Station.....	Fayette.....	Calcareous sandstone.....	37, 740
6097	Bidwell.....	do.....	Limestone.....	13, 450
9347	Connellsville.....	do.....	do.....	26, 050
5604	Water Street.....	Huntingdon.....	Feldspathic sandstone.....	22, 330
5557	Walford.....	Lawrence.....	Limestone.....	27, 500
10518	Montoursville.....	Lycoming.....	Argillaceous limestone.....	23, 460
10672	Jersey Shore.....	do.....	Siliceous limestone.....	20, 360
6153	Porter Township.....	do.....	Argillaceous limestone.....	28, 580
6154	do.....	do.....	do.....	26, 860
6155	do.....	do.....	do.....	18, 610
6156	do.....	do.....	do.....	22, 930
6157	do.....	do.....	Limestone.....	21, 900
6158	do.....	do.....	do.....	14, 160
7980	Port Allegheny.....	McKean.....	Feldspathic sandstone.....	9, 680
8022	(1).....	(1).....	Ferruginous sandstone.....	12, 130
8023	(1).....	(1).....	do.....	14, 000
8024	(1).....	(1).....	do.....	12, 480
11190	Shohola.....	Pike.....	Feldspathic sandstone.....	25, 250
9812	Holmesburg.....	Philadelphia.....	Biotite gneiss.....	21, 530
3243	McSpadden.....	Somerset.....	Sandstone.....	26, 900
10345	Confluence.....	do.....	Calcareous sandstone.....	24, 790
5830	Prompton.....	Wayne.....	Feldspathic sandstone.....	26, 340
5605	Blairsville Intersection.....	Westmoreland.....	Siliceous limestone.....	32, 560
7428	York.....	York.....	Dolomitic marble.....	27, 400

RHODE ISLAND.

8867	Westerly.....	Washington.....	Granite.....	11, 740
8868	do.....	do.....	do.....	20, 300
8869	do.....	do.....	do.....	20, 750

SOUTH CAROLINA.

8389	Williamstown.....	Anderson.....	Granite.....	12, 990
5568	Rion.....	Fairfield.....	do.....	29, 180
5586a	do.....	do.....	do.....	25, 790
5586b	do.....	do.....	do.....	19, 240
5586c	do.....	do.....	do.....	33, 880
10531	do.....	do.....	Biotite granite.....	25, 540

TENNESSEE.

5597	Quarry.....	Carter.....	Limestone.....	22, 750
5502	Straw Plains.....	Jefferson.....	do.....	21, 730
5504	do.....	do.....	do.....	28, 340
5503	do.....	do.....	Dolomite.....	38, 070
6533	Knoxville.....	Knox.....	Marble.....	17, 970

VERMONT.

5543	East Wallingford.....	Rutland.....	Altered diabase.....	16, 800
8853	Barre.....	Washington.....	Granite.....	19, 560

¹ Exact locality not known.

TABLE II.—Results of compression tests of rock complete to Jan. 1, 1917—Continued.

VIRGINIA.

Serial No.	Locality.	County.	Name.	Crushing strength, pounds per square inch.
8804	Albert.....	Bedford.....	Granite gneiss.....	13, 820
10344	Lynchburg.....	Campbell.....	Quartzite.....	25, 885
6796	(¹).....	Dinwiddie.....	Granite.....	13, 150
4900A	Broad Run.....	Fauquier.....	Quartz.....	28, 400
4900B	do.....	do.....	Epidosite.....	28, 000
5923	Strathmore.....	Fluvanna.....	Chlorite epidote schist.....	13, 210
5678	Eggleston (near).....	Giles.....	Dolomite.....	45, 690
5924	Boscobel.....	Goochland.....	Granite gneiss.....	13, 550
6615	Korah Station.....	Henrico.....	Biotite granite.....	20, 300
5925	Greenway.....	Nelson.....	Feldspathic quartzite.....	16, 500
5492	Nokesville.....	Prince William.....	Ferruginous sandstone.....	17, 780
5920	Greenlee.....	Rockbridge.....	Dolomitic marble.....	36, 900
5382	Bluff Water Station.....	Rockingham.....	Limestone.....	21, 450
5385	do.....	do.....	do.....	40, 850
5375	St. Paul.....	Russell.....	do.....	17, 600
7217	Burkes Garden.....	Tazewell.....	Dolomitic sandstone.....	21, 500

WEST VIRGINIA.

5365	Berkeley.....	Berkeley.....	Limestone.....	23, 350
5917	Renick.....	Greenbrier.....	Crystalline limestone.....	21, 300
5918	Frazier.....	do.....	Limestone.....	17, 450
5919	Snow Flace.....	do.....	do.....	13, 550
7475	Green Spring, east of.....	Hampshire.....	Siliceous limestone.....	34, 400
7476	do.....	do.....	Quartzite.....	15, 050
6109	Spring Hill.....	Kanawha.....	Sandstone.....	12, 400
9132	Fairmont.....	Marion.....	do.....	5, 420
9133	do.....	do.....	do.....	5, 720
9134	do.....	do.....	do.....	6, 080
5610	Sturgeson.....	Monongalia.....	Siliceous limestone.....	22, 440
5612	do.....	do.....	Limestone.....	17, 910
5613	do.....	do.....	Argillaceous limestone.....	14, 300
5614	do.....	do.....	Calcareous sandstone.....	29, 840
5615	do.....	do.....	Impure limestone.....	19, 650
5616	do.....	do.....	Argillaceous limestone.....	24, 850
8447	Parkersburg.....	Wood.....	Feldspathic sandstone.....	11, 910

WISCONSIN.

5523	Peebles.....	Fond du Lac.....	Dolomite.....	32, 600
3448	Amberg.....	Marinette.....	Biotite granite.....	20, 000
11129	Wauwatosa.....	Milwaukee.....	Argillaceous dolomite.....	45, 310
8656	Lannon.....	Waukesha.....	Dolomite.....	23, 020

¹ Exact locality not known.

TABLE III.—Geographical distribution of rock samples tested to Jan. 1, 1917.

Alabama.....	31	Kansas.....	13	New Jersey.....	75	Utah.....	13
Arizona.....	3	Kentucky.....	46	New Mexico.....	1	Vermont.....	35
Arkansas.....	17	Louisiana.....	7	New York.....	148	Virginia.....	424
California.....	101	Maine.....	86	North Carolina.....	149	Washington.....	213
Colorado.....	28	Maryland.....	121	Ohio.....	165	West Virginia.....	180
Connecticut.....	52	Massachusetts.....	192	Oklahoma.....	50	Wisconsin.....	149
Delaware.....	30	Michigan.....	95	Oregon.....	14	Wyoming.....	3
Florida.....	13	Minnesota.....	17	Pennsylvania.....	610	Canada.....	52
Georgia.....	256	Mississippi.....	13	Rhode Island.....	41	Porto Rico.....	12
Idaho.....	10	Missouri.....	39	South Carolina.....	30	Cuba.....	4
Illinois.....	128	Montana.....	4	South Dakota.....	15		
Indiana.....	179	Nebraska.....	12	Tennessee.....	77		
Iowa.....	23	New Hampshire.....	27	Texas.....	63	Total.....	4, 066

By comparing the results of tests on a sample of rock with the limits as shown in the following table, a general idea of the types of road construction for which it is best suited may be obtained.

TABLE IV.—General limiting test values for broken stone.

Type of construction.	Traffic. ¹	Limiting values.		
		French coefficient of wear.	Toughness.	Hardness.
Water-bound macadam, plain or with dust palliative treatment.	Light.....	5 to 8	5 to 9	10 to 17
	Moderate.....	9 to 15	10 to 18	14 or over.
	Heavy.....	16 or over.	19 or over.	17 or over.
Macadam with bituminous carpet.....	Light to moderate..	5 or over.	5 or over.	(²)
Bituminous macadam with seal coat.....	Moderate to heavy..	7 or over.	10 or over.	.....
Bituminous concrete.....	Light to moderate..	7 or over.	7 or over.	(²)
	Moderate to heavy..	10 or over.	13 or over.	.....
Binder course for sheet asphalt or Topeka type.	Any.....	7 or over.	6 or over.	(²)
Portland cement concrete.....	Moderate to heavy..	(³)	8 or over.	16 or over.
Stone paving block ⁴	Any.....	(³)	9 or over.	16 or over.
Broken stone foundations.....	.do.....	3 or over.	3 or over.	8 or over.
Cement concrete foundations.....	.....	.....	.....	.....

¹ Light traffic is assumed as less than 100 vehicles per day, moderate traffic between 100 and 250 vehicles, and heavy traffic over 250 vehicles per day.

² Numerous tests have shown that limits for hardness are unnecessary if the material possesses the required French coefficient of wear and toughness.

³ Limits for French coefficient of wear are not at present considered necessary for this type of construction.

⁴ Crushing strength, 20,000 pounds or over per square inch is sometimes required.

Cementing values should show over 25 in all cases if material is to be used in water-bound macadam construction.

In general, granites, gneisses, schists, sandstones, and quartzites should not be used in the wearing course of water-bound macadam roads. Shales and slates never should be used in this connection; therefore cementing value tests have been discontinued on these materials.

For further details and explanation of results in this table and also for tests on all materials to January 1, 1916, see U. S. Department of Agriculture Bulletin No. 370.

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BULLETIN No. 538



Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C.

June 27, 1917

SHRIMP: HANDLING, TRANSPORTATION, AND USES.

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That both raw and cooked shrimp can be shipped to distant markets without the use of preservatives and arrive in good condition is established both by the experience of careful packers and by the investigations reported in this bulletin. To do this, however, the handler must observe two precautions. In the first place, he must keep raw shrimp iced or cold from the time they are caught until they reach the consumer. Secondly, he must wash the raw shrimp thoroughly, as soon as possible, in order to remove slime and foul stomach contents which are likely to contaminate the product and give it an unsatisfactory color or flavor after it has been cooked. Careful handling is necessary at every stage to avoid unnecessary breaking or damaging of the shrimp.

ICING.

Unless they are iced or cooled immediately when caught, shrimp will soften quickly, especially in warm weather. Whenever there is danger of such softening, shrimp boats or trawlers should carry plenty of ice. Shrimp buyers should refuse to take stock that is not in good condition at the dock. Heavy icing is particularly important when the shrimp are molting, because then they are soft, easily broken in handling, and more subject to decomposition.

Care in handling shrimp properly begins the moment the net is raised. All soft, damaged, or small shrimp should be culled out and

the slime and dirt removed by thorough washing with water. Culled and cleaned shrimp should be stored in the boat at once with cracked ice. As soon as the boat reaches the dock the shrimp should be removed from the hold, sorted a second time, and weighed. Unless the stock is to be headed at once, or is to go immediately to the kettle, the shrimp should be placed in cooling tubs filled with cracked ice and water, or go into a refrigerated room, the temperature of which is below 40° F., and allowed to stand there for several hours until completely chilled. When shrimp are to be shipped raw they should always be thoroughly chilled before shipment. If the chilling is thorough, less ice will be required in transit and the stock will be firm when delivered.

HEADING.

In certain sections the trade demands headless stock. In other markets, especially in the South, consumers are suspicious of headed shrimp, as they erroneously regard the absence of the head as an indication of spoiled stock. Such consumers ultimately pay the express on the entire weight of the package and then throw nearly half of the shrimp away. Experiments indicate that the heads and appendages constitute from 43 to 45 per cent of the raw whole stock and about 41 per cent of the cooked whole stock.

It is essential that the shrimp be headed before they have become warm, because the dark liquid in the stomach of the shrimp consists of oily, partially digested plant and animal material, which readily decomposes. This liquid, as well as the body slime, must be removed immediately after the shrimp are headed.

COOKING.

THE BRINE.

The crude, haphazard methods of cooking practiced in some plants explain in large part the losses in cooked shrimp and the unpalatability of some products. Such "rule-of-thumb" methods as cooking until the meat pulls away from the back of the shell will not give uniform results. The careful packer when cooking seeks to sterilize the shrimp by the heat and to let the stock absorb enough salt from the brine to insure proper seasoning and to promote keeping qualities. At the same time the packer must control his operation so as to prevent excessive loss in weight from overcooking and loss in quality from undue hardening and salting of the meat. Undercooking is also to be guarded against, as it results in a flabby, tasteless product, poor in keeping quality.

The initial step in cooking first-class stock is to use brines of proper strength. No definite rules can be laid down as to the strength

of the brine, as this will depend on the relative amounts of shrimp and brine used, the time allowed for cooking, and the degree of saltiness desired. Each packer, by experiment, can determine readily the strength of brine and the length of cooking which will yield the results he desires. In general, the brine should contain not less than 10 per cent, by weight, of salt and not more than 25 per cent. There should be at least 4 gallons of brine for each 10 pounds of shrimp. The careful packer will equip himself with a hydrometer so that he can measure accurately from time to time the density of his brine.

THE COOKING VESSEL.

The shape of the vessel in which the shrimp are cooked directly affects the evaporation of water from the brine, and consequently has a bearing on the density of the brine during cooking. Deep kettles with straight sides that have as little surface as possible for loss of heat and for evaporation, are the most satisfactory. They should be heated from some constant source—preferably coils of steam pipes immersed in the brine—which permits of exact control of temperatures. It is not desirable to cook shrimp in metal tubs, in pots, or in wide, shallow kettles over open fires.

LENGTH OF COOKING.

It is very important to have the brine actually bubbling before any shrimp are put into the kettle. Cold shrimp will chill the brine so that it stops boiling, but if the volume of liquid is sufficiently large, active boiling will be resumed within a few minutes. Since the shrimp in cooking develop air spaces and rise to the surface, they should be held down by a weighted wire screen or similar device to insure proper cooking.

The length of cooking depends upon the strength of the brine, the quantity of shrimp to be cooked, and the flavor desired. In general, shrimp are cooked from 15 to 20 minutes after the brine in which they have been placed begins to boil. The shorter the cooking and the weaker the brine the less will be the shrimp's loss in weight. When a minimum amount of salt is used, continuous refrigeration is necessary in order to prevent spoilage, and the product is suitable only for shipping to near-by markets. Shrimp that will be shipped to distant markets should first be cooked in 15 per cent brine for 15 to 20 minutes, cooled in a chill room to 35° F., or less, and then shipped in a sealed package surrounded by ice,.

ACCURATE CONTROL OF COOKING.

To insure accurate cooking, the packer should use a thermometer which registers as high as 250° F. It should be made entirely of glass, as brine affects wood or metal frames. The packer should also have

a hydrometer graduated in salt percentages, Baumé scale, or specific gravity. Hydrometer readings should be taken only in cool brines, the temperature of which is as near 60° F. as possible. With these instruments the packer can determine readily by a few experiments the best brine and the best temperature as related to time of cooking. Cooking for 15 minutes in a 15 per cent brine might be used as a starting point in these experiments.

The following table shows the approximate relationship between the boiling points, densities, and specific gravity of the brines, and the amounts of salt needed to make a brine of given percentage. In ordinary practice, however, it is necessary to have from 10 to 20 per cent more than the specified amount of salt. As commercial salts vary in impurities and moisture content, this table is suggested only as a guide. It must be modified after experiment to fit the particular salt used.

TABLE 1.—*Approximate relationships between boiling points and strength of brine.*

Salt.	Boiling point of brine.	Specific gravity of brine at 60° F.	Density of brine at 60° F.	Dry salt required for 100 gallons of brine.
<i>Per cent.</i>	<i>° F.</i>		<i>° Baumé.</i>	<i>Pounds.</i>
5.0	214	1.035	5.0	43
7.5	216	1.054	7.4	65
10.0	217	1.073	9.8	86
12.5	219	1.092	12.2	113
15.0	221	1.112	14.5	139
17.5	223	1.131	16.7	165
20.0	225	1.152	19.0	191
25.0	228	1.192	23.2	230

COOKING WITH LIVE STEAM.

Live steam, occasionally used for cooking headed shrimp that are intended for drying, may also be employed in cooking shrimp for ordinary purposes. The shrimp are sprinkled evenly with salt and allowed to stand a short time. They are then placed in a steam-tight box and subjected to the action of live steam for half an hour. This process, aside from obviating the necessity for making and handling brines, requires less salt, prevents soaking out of flavors, and results in less loss in weight. Where brine is used, chemical analysis of the scums and brines after cooking shows that considerable amounts of albuminous and mineral matter have passed from the shrimp into the brine. The albumin coagulates upon boiling in much the same manner as does the white of an egg. This loss in albuminous and mineral matter means that the shipper loses, since he has fewer pounds of shrimp to ship, and that the consumer does not receive the full food value of the product.

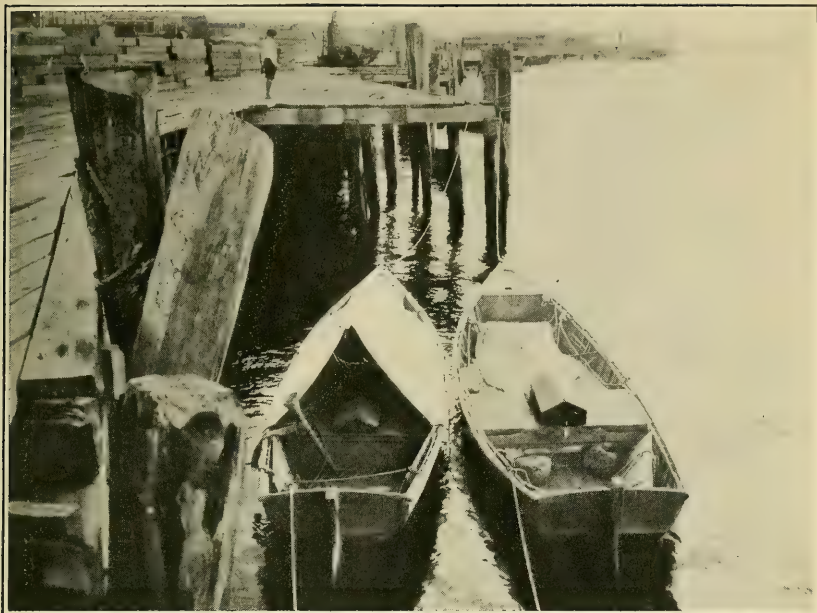


FIG. 1.—TRAWL NET BOATS USED FOR CATCHING SHRIMP.

BC-FRL-S-1

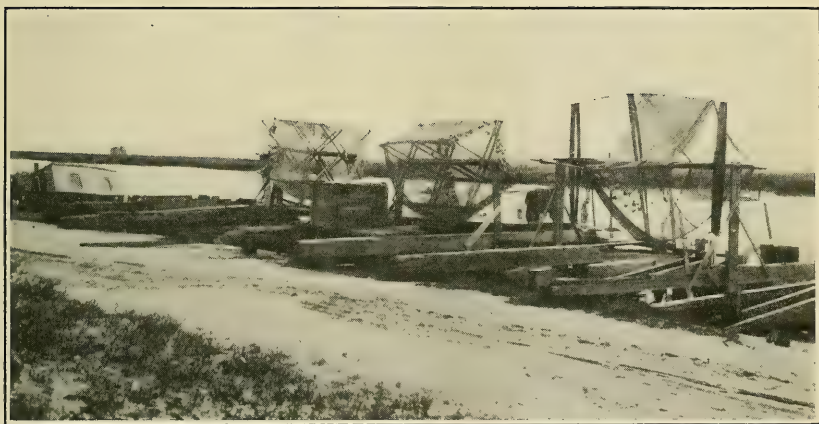


FIG. 2.—SHRIMP IN SHALLOW WATER ON THE BEACHES ARE CAUGHT IN THESE LONG NETS BY WADING MEN.

BC-FRL-S-2



BC-FRL-S-3

FIG. 1.—BOILING SHRIMP OVER OPEN FIRES BY “RULE-OF-THUMB” METHODS IS LARGELY RESPONSIBLE FOR THE LOW QUALITY SHRIMP SOMETIMES FOUND IN NORTHERN MARKETS.



BC-FRL-S-4

FIG. 2.—SHRIMP HEADS. A VALUABLE FERTILIZER NOW GOING TO WASTE.

PREPARING COOKED SHRIMP FOR MARKET.**COOLING SHRIMP AFTER COOKING.**

After they have been cooked the shrimp should always be cooled thoroughly before being packed for shipment. Unless this cooling is done properly they can not be shipped to market successfully. The spoilage of shrimp in transit is due more to incomplete chilling before packing than to any other single factor.

The shrimp should be placed in thin layers on cooling racks of wire screens in a temperature below 50° F., if possible, and exposed to a free circulation of air. Under this treatment the shrimp quickly lose their heat and the excess of water absorbed from the brine. The packer should not judge their temperature merely by touching the shells. Cooked shrimp contain air spaces between the meat and the shell and as the shell is a poor conductor it frequently is cold to the touch even when the shrimp meat itself is still warm. The degree of cooling may be tested by removing a shell and breaking open the meat.

In the Southern States the temperature of the air may be from 75° to 90° F. This is too warm to cool the shrimp to the degree necessary in the case of such a perishable foodstuff. Under such conditions the shrimp must be placed in a refrigerated room. Proper cooling is of the greatest importance because it means less danger of spoilage in transit, results in the use of less ice in packing, and insures freshness in the product when it reaches the market.

PACKING COOKED SHRIMP FOR SHIPMENT.

There are several ways to pack shrimp, depending on the demands of the markets and the distances to which the shrimp are shipped. For near markets whole or headless cooked shrimp are packed in small boxes or crates and shipped in the cool months, usually without refrigeration. The containers should not hold over 30 pounds, as a larger bulk increases the danger of heating. Unless the shrimp are absolutely dry and cooled to a temperature of less than 40° F. it is hazardous to ship them in air-tight containers because of danger of sweating and consequent decomposition. For this reason some packers use ventilated containers or crates.

Dry cooked shrimp are thoroughly cooled, packed, and sometimes shipped in 1 to 5 gallon tin cans that are lined with paper and provided with water-tight covers or tops which are soldered or fastened tightly to the can. The sealed cans then are packed in ice in burlap-covered barrels with drainage holes at the bottom. Such packages are reiced by the express company when necessary, and even in warm weather can be transported in good condition.

Some shippers pack the cooked stock in tight cans in light brine supposed to act as a preservative. The dry-packed stock, however,

has a better flavor and keeps just as well if it has been properly cooked and handled. Packing brines should not be over 5 to 10 per cent strength. Heavier solutions tend to make the shrimp leathery and too salty and weaker ones produce softness and flabbiness in the stock and have no appreciable preservative effect. A brine of 7 or 8 per cent strength should be satisfactory for shipping purposes. In such packing both shrimp and brine should be cooled before shipping; otherwise there is danger that the ice may melt during transit and the shrimp consequently decay.

Headless cooked shrimp packed in kegs in strong brine of from 15 to 20 per cent strength keep very well. This "keg stock" sometimes is used in restaurants or hotels, where the necessary freshening can be done. Most housewives prefer the product packed in weak brine because it is more convenient and has a better flavor.

PACKING RAW SHRIMP FOR SHIPMENT.

Raw shrimp before being packed are chilled with ice to 40° F. or below. A layer of ice is placed in the bottom of a barrel provided with drainage holes. A layer of chilled shrimp is placed on the ice, then another layer of ice, and more shrimp. A large cake of ice or "header" is placed on the top of the barrel. Another method is to provide a bottom layer of ice and then place on end in the center of the barrel a long, narrow cake of ice. The shrimp are packed around this cake, or core, of ice, the "header" cake is placed on top of the barrel, and the barrel and its contents covered with burlap. Cooked shrimp, as a rule, are sent by express in small lots. In the case of raw shrimp, car lots of iced barrels occasionally may be shipped by fast freight in refrigerator or ventilator cars.

DRIED SHRIMP AND OTHER SPECIALTIES.

Dried shrimp are prepared in certain sections of Louisiana and Florida. The cooked shrimp are dried outdoors in the sun and the meats threshed out from the shells. Under an improved process raw shrimp sprinkled with salt are cooked with live steam and dried over steam pipes. This rapid drying results in a bright, attractive food product which has not been subjected to the molding or decomposition frequently taking place when shrimp are dried outdoors under varying weather conditions. This product deserves a wider market.

Headed and peeled shrimp meats also should prove popular. These meats after being cooked in a weak brine are cooled and dried on wire screens. They are then packed dry in tightly sealed tin cans (sometimes lined with paper) of from 1 to 5 gallon capacity. The cans are shipped in barrels of cracked ice.

Shrimp pastes are prepared by grinding shrimp meats and adding salt and flavoring. They are used like anchovy paste for sandwiches

and as a relish. Potted tuna fish, smoked salmon paste, and similar preparations of halibut have recently met with some sale in this country. It is believed that a somewhat similar by-product can be made profitably from broken or small shrimp or from surplus stock taken in periods of slack markets.

FOOD VALUE OF SHRIMP MEAT.

Chemical analysis shows that shrimp are a nitrogenous food containing constituents similar to those found in cheese, meat, oysters, and eggs. Almost all of the edible portion of raw shrimp is protein, the muscle and tissue building food element. Since shrimp are a concentrated nitrogenous food they may be used as the principal dish of a meal as well as the basis of a salad or as an appetizer or relish.

Table 2, which shows the results of analyses of shrimp obtained from different localities and prepared in various ways, gives comparisons between shrimp and other foodstuffs of a nitrogenous nature.

TABLE 2.—*Analyses and food values of shrimp and certain other foodstuffs.*

[Calculated on the fresh basis.]

Constituents.	Shrimp (edible portion).				Other foods (edible portion).							
	Cooked.	Canned (dry packed).	Canned (wet packed).	Dry.	Scallops.	Oysters, shucked.	Canned salmon.	Fresh halibut.	Whole egg.	Beefsteak, lean.	Whole milk.	American cheese.
	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. et.</i>	<i>P. ct.</i>	<i>P. ct.</i>
Protein.....	27.6	25.5	20.0	71.4	14.8	6.2	21.8	18.6	13.4	21.3	3.3	28.8
Carbohydrates.....						3.4						
Fat.....	1.0	0.8	0.5	5.0		1.2	12.1	5.2	10.5	7.9	5.0	35.9
Water.....	64.5	67.7	75.7	12.5	80.3	86.9	63.5	75.4	73.7	70.0	87.0	31.6
Salt.....	4.8	2.9	1.9	6.8			1.0					1.7
Comparative fuel value per pound (calories)...	559	505	395	1,540	345	235	915	565	720	730	325	2,055

UTILIZATION OF SHRIMP WASTE.

When shrimp are headed about 43 per cent of their weight is thrown away. Small amounts of this material are used locally by farmers, who report that it has excellent fertilizing value for certain crops. As a thousand barrels of shrimp (50,000 to 60,000 pounds) are landed sometimes in a single day it is obvious that a large amount of potentially valuable fertilizing material is obtained from the heading of shrimp. Some attention has been given to the drying of shrimp heads for sale as fertilizer. Experiments indicate, however, that in the process of drying a large amount of nitrogen is lost in the form of ammonia or other volatile substances. To retain this nitrogen it would seem advisable to mix the material before drying with a suitable acid-reacting substance of value as a fertilizer. The material

when dried in this manner should constitute a valuable by-product. Analysis shows that dried shrimp waste contains over 11 per cent nitrogen, calculated as ammonia, and $2\frac{1}{2}$ per cent phosphorus, calculated as phosphorus pentoxid. These figures indicate high fertilizing value.

SUMMARY.

Cleanliness, proper cooking, and care in handling shrimp, combined with a discontinuance of the practice of using preservatives, have resulted in the production of a finely flavored product which is gradually increasing in popularity. At the same time improvements in methods of packing and preparation have made shrimp accessible to many new markets at long distances from the producing sections.

Packers in the South and on the Pacific Coast should make every effort to keep their own products up to the highest standard and should do everything possible to promote the general adoption of high standards by the trade.

The increased consumption of shrimp and the opening of new markets are stimulating the industry to increase its catches. If shrimp are taken at the wrong time of year or in excessive numbers their extermination is probable. Those interested in the shrimp industry, therefore, should give early attention to the question of conservation. It is also to the interest of those whose livelihood is dependent upon catching and packing shrimp to encourage investigations planned to determine the periods of spawning, the times of migration, and the feeding habits of shrimp, and to do their part in helping to make such investigations result in the adoption of protective measures.

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L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER.

September 8, 1917

THE LESSER CORN STALK-BORER.¹

By PHILIP LUGINBILL and GEO. G. AINSLIE, *Entomological Assistants, Cereal and Forage Insect Investigations.*

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INTRODUCTION.

Although the lesser corn stalk-borer (*Elasmopalpus lignosellus* Zell.) heretofore has occurred in injurious abundance only in sporadic outbreaks, it now has become an insect of considerable economic importance in the Southern States, since crops grown in the poorest types of soils, or in soils lacking humus, are usually the most seriously affected. The injuries to plants by larvæ of this species sometimes resemble closely those of certain beetle larvæ commonly known as "budworms" (*Diabrotica 12-punctata* Fab.) and it seems probable that injuries frequently attributed to the latter are in reality the work of the lesser corn stalk-borer.

While engaged in other investigations early in the season of 1913 near Columbia, S. C., the senior author was informed by the authorities superintending the State farm near that city that the lesser corn stalk-borer was responsible for considerable damage to their field crops almost every year. Investigations begun immediately were continued through 1914 and 1915. The junior author, while engaged in certain investigations in Florida during the winter of 1913-14, encountered this same species in destructive numbers.

The following paper, therefore, is a compilation of the results obtained from studies made at Columbia, S. C., during the years 1913-1915 by the senior author (27)² and at Lakeland, Fla., in 1913-1914, by the junior author.

¹ The authors wish to acknowledge the cooperation of A. H. Beyer and H. L. Dozier in field investigations.

² Reference is made by number to "Literature cited," p. 25.

ECONOMIC HISTORY.

Although the lesser corn stalk-borer was originally described by Zeller (3) in 1848, and was known to scientific workers from several parts of the Western Hemisphere, it was not until 1881 that it began to have other than a purely scientific interest. In July, 1881, C. V. Riley, then entomologist of the United States Department of Agriculture, was notified that an insect (later identified as this species) was injuring corn, both old and young, in the vicinity of Augusta, Ga. Steps were taken at once to learn more of the life history and habits of the pest, and agents of the Division of Entomology spent the remainder of the year conducting investigations at these points in order that they might be able to propose remedial or preventive measures. The studies made at that time showed that this insect had not been known as a pest until about 1878, and that during the period 1878-1881 it had become of economic importance in Georgia and South Carolina, specimens being taken even as far north as Chapel Hill, N. C. The life history was partly worked out and published by Dr. Riley (8, 9, 10)¹; but, as no further complaints were received, the investigation was suspended.

In a discussion of the corn insects of Nebraska, Prof. Lawrence Bruner (14) published a brief account of this species and its work, but did not state that it had been found in Nebraska. In 1884 (11) and again in 1893 (16) Riley listed it as injurious to the stalk of corn.

Not until nearly twenty years after the first recorded damage did it again become the object of special study by entomologists. In 1899 Dr. F. H. Chittenden, of the Bureau of Entomology, received complaints of injury to beans by the insect in Alabama and South Carolina, and also to peanuts in Georgia (19). Specimens of the insects sent to Washington were identified as *Elasmopalpus lignosellus*, and further biological studies were begun. All the available information at this time was brought together, and the results published in Bulletin 23 of the Division of Entomology by Dr. Chittenden (18). A brief note by Dr. Chittenden (21) in Bulletin 40 of the Bureau of Entomology, published in 1903, reported damage to cowpeas in Texas and Virginia, and the Yearbook of the United States Department of Agriculture for 1903 (22) records injury to cowpeas, beans, and soy beans in Texas, Alabama, and Virginia, part of these records undoubtedly being repetitions of those given in Bulletin 40. In 1904 Titus and Pratt (23) listed it as injurious to corn, beans, and peas.

Dr. S. A. Forbes (24) included this species in his monograph of the insects injurious to corn, drawing largely from Riley's account in describing its habits and methods of attack. He added the information, however, that adults had been taken in Illinois in August

¹ See "Literature cited," p. 25.

and September, but the account does not indicate that the species caused damage in the State at that time.

In 1905, as reported in the Yearbook of the United States Department of Agriculture for that year (25), sorghum, cowpeas, and crabgrass were totally destroyed in some fields near Columbia, S. C., and reports of damage were received from other localities in South Carolina and Georgia. On November 4, 1915, the junior author also found at Nashville, Tenn., a small wheat plant killed by a larva which was nearly full grown and which entirely filled the burrow that it had excavated in the stem.

SYSTEMATIC HISTORY AND SYNONYMY.

The lesser corn stalk-borer was first described by Zeller (1) from Brazil, Uruguay (Montevideo), and Colombia, South America, and a single female from "Carolina," U. S. A. In this article, aside from the specific description, Zeller describes three unnamed varieties, basing his descriptions almost entirely on color variations. No further notes are given in this account except from the localities listed. Four years later Blanchard (2) redescribed the species under the name *Elasmopalpus angustellus*, erecting for its reception the genus *Elasmopalpus*, which recently has been accepted as the proper position for the species. Not until two decades later is there a further reference to the species in the literature, when Zeller (3), in an article dealing with some North American moths, adds somewhat to our knowledge of its seasonal and geographical distribution, recording it from Brazil and Colombia, in South America, and "Carolina" and Texas, in the United States. At the latter place three females were taken, one on July 15 and the other two a month later. He also adds the descriptions of two varieties, *incautella* and *tartarella*, based on color variations. Each of these varieties was described from a single specimen, and both were taken at the same place and on the same date. The species as a whole is extremely variable and Zeller himself in a later publication (7) placed *incautella* as a synonym of *lignosella* though still retaining *tartarella* as a valid variety. Another variety, designated as "variety B," was described by Zeller (4) from material collected at Valparaiso, Chile. In 1875, Berg (5), using material taken in Patagonia and elsewhere in southern South America, supplemented Blanchard's description of *E. angustellus*, going into detail, particularly in describing the venation, and two years later, in a further paper on Patagonian insects (6), came to the conclusion that the species he had been considering Blanchard's *angustellus* was Zeller's *lignosella*. Since both the species are genotypes, the reduction of *angustellus* to a synonym of *lignosella* made *Elasmopalpus* a synonym of *Pempelia*, where it remained until revived by Hulst in 1890 (13) for this same species. In 1881 Zeller (7) gave some notes on the amount

of variation in the species, basing his remarks on a collection of 25 specimens from Colombia, South America, most of them taken in September and October.

Hulst (12) redescribed this species as new, from Texas, under the name *Dasyphyga carbonella*, a mistake which he later rectified in his monograph of the Phycitidae (13), in which he places *carbonella* as a synonym of Zeller's variety *tartarella*. In the same publication he redescribes *lignosellus*, places it in the genus *Elasmopalpus* for the first time under that name, and gives a bibliography and notes on the distribution and seasonal occurrence.

Ragonot (15) covers much the same ground as several of the previous authors, giving the synonyms, bibliography, and a description of the species and calling attention to its great variability. He also uses the name *major*, the first word of Zeller's description, for the variety *B* mentioned above and lists it as a variety of the species *lignosellus*. Smith (17 and 26) records the species from New York, and Dyar (20) lists it with its synonyms in his catalogue of the Lepidoptera of North America, giving the distribution as the Atlantic States and South America.

The junior author has gone carefully over all the descriptions given by the various authors mentioned above, examining the specimens in the United States National Museum, and has come to the conclusion that the use of all varietal names in this species may well be discontinued. The varieties that have been described are not constant in any respect either as to size, geographical distribution, or seasonal occurrence, and apparently they indicate merely individual aberrations in color, size, or markings. The synonymy, then, stands as follows:

- Pempelia lignosella* Zeller (1),
- Elasmopalpus angustellus* Blanchard (2),
- Pempelia lignosella tartarella* Zeller (3),
- Pempelia lignosella incautella* Zeller (3),
- Dasyphyga carbonella* Hulst (12),
- Elasmopalpus lignosellus* (Zeller) Hulst (13),
- Elasmopalpus lignosellus incautellus* (Zeller) Hulst (13),
- Elasmopalpus lignosellus tartarellus* (Zeller) Hulst (13).

GEOGRAPHICAL DISTRIBUTION.

This species is limited in its occurrence to the Western Hemisphere. It occurs practically throughout South America, having been reported from widely separated localities in all parts of that continent. The list as given by Hulst includes Venezuela, Colombia, Brazil, Argentina (Buenos Aires), Chile, and "Patagonia." In North America (fig. 1), while its range is not so great, it may be said to occur over the entire southern half of the United States. It has been most

commonly reported from the States bordering the Gulf of Mexico and the southern Atlantic coast. It has been encountered causing injury in Arizona. Dr. Forbes reports it as having been taken at various points in southern Illinois. There is a specimen in the National Museum rather indefinitely labeled "Iowa." The late Prof. F. M. Webster observed some of the moths years ago at Lafayette, Ind. In addition to the one mentioned above there are specimens in the National Museum bearing locality labels indicating that the moths have been taken at Cohasset, Mass.; Clemson College, S. C.; Miami, Palm Beach, and Lakeland, Fla.; New Orleans, La.; Dallas, Brownsville, Sabinal, Kerrville, Victoria, and Burnet County, Tex.; and San Diego, Cal. John B. Smith, in his List of the Insects of New Jersey, records it from Newark and Montclair and states that it will

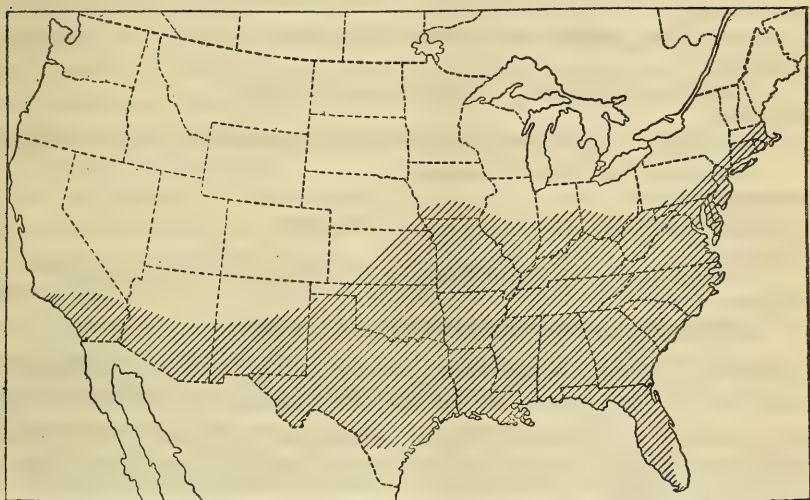


FIG. 1.—Map showing present known distribution of the lesser corn stalk-borer (*Elasmopalpus lignosellus*) in the United States. (Original.)

be found throughout the State. It undoubtedly occurs throughout Mexico and has been reported from the Bahama Islands.

FOOD PLANTS.

The following is a list of food plants upon which the larvæ of this species have been found to feed, given here with locality, date, and collector or observer:

BEANS:

Auburn, Ala., August 16, 1889 (F. S. Earle); Charleston, S. C., September 27, 1889 (H. M. Simmons).

CORN (*Zea mays*):

Augusta, Ga., 1881 (C. V. Riley); Illinois, 1905 (S. A. Forbes); Lakeland, Fla., April 25, 1913 (Geo. G. Ainslie); Columbia, S. C., 1913–1914 (P. Luginbill); Tempe, Ariz., October, 1914 (Edmund H. Gibson).

COWPEAS:

Victoria, Tex., August 30, 1902 (W. D. Hunter); Fredericksburg, Va., September 2, 1902 (G. W. Koiner); Columbia, S. C., and other points in the State, and Georgia, 1905 (F. M. Webster); Columbia, S. C., 1914 (P. Luginbill); Gainesville, Fla., July and August, 1916 (R. N. Wilson and H. L. Dozier); Boca Grande, Fla., June 29, 1916 (H. L. Dozier); Arcadia, Fla., June and July, 1916 (Joseph Crews).

CHUFA (*Cyperus esculentus*):

Arcadia, Fla., June and July, 1916 (Joseph Crews).

CRAB GRASS (*Eleusine indica*):

Columbia, S. C., other points in the State and Georgia, 1905 (F. M. Webster); Columbia, S. C., August 27, 1913 (P. Luginbill).

JAPANESE CANE:

Arcadia, Fla., June and July, 1916 (Joseph Crews).

JOHNSON GRASS:

Tempe, Ariz., November 3, 1914 (Edmund H. Gibson).

MILO MAIZE:

Tempe, Ariz., October, 1914 (Edmund H. Gibson).

PEANUTS:

Athens, Ga., September 25, 1889 (Thomas I. Todd).

SORGHUM:

Columbia, S. C., other points in the State and Georgia (F. M. Webster); Columbia, S. C., 1913-1915 (P. Luginbill).

SUGAR CANE:

New Orleans, La., June 16, 1914 (T. E. Holloway).

TURNIPS:

Athens, Ga., October, 1889 (Thomas I. Todd), feeding on the leaves.

WHEAT:

Nashville, Tenn., November 4, 1915 (Geo. G. Ainslie).

Although it would seem from the above that the larvæ are omnivorous, the investigations of the writers disclose the fact that they show a decided fondness for the Gramineæ and probably would confine themselves almost exclusively to plants belonging to this order if always obtainable.

RECENT INJURIES.

This species is particularly injurious because it shows a decided fondness for attacking plants growing in sandy soil. Soil of this type generally is deficient in fertilizing elements and also suffers very quickly from drought. Consequently plants growing in such soil are not as thrifty and vigorous as those growing in loamy soils, and when attacked they lack vitality to counteract the injury and suffer more than do those in soils of more favorable nature. It frequently occurs that only certain portions of the field are of this sandy type and in such cases infestation is confined to the sandy areas, it often being difficult to find larvæ in the rest of the field.

During the summer of 1913 about 2 acres of sorghum in a field on the State farm near Columbia, S. C., was practically laid waste by the ravages of this species. The soil in this area was almost pure sand, while the rest of the field was sandy loam. In many instances,

as shown in Plate I, figure 2, no trace of plants could be found when the photograph was taken, the larvæ having killed them outright when young. Those that did survive were much dwarfed and rendered practically worthless, and in most instances were devoid of central stems.

In the latter part of April, 1913, fields of small corn near Lakeland, Fla., were being attacked and ruined by these larvæ, about 10 per cent of the plants exhibiting evidences of injury at this time. The plants continued to die for about 10 days, at the end of which time in some portions of the fields fully 90 per cent were dead and the stand everywhere was poor. The parts of the fields most lacking in humus suffered the greatest injury. During the same year considerable damage was done to cowpeas in fields near Columbia, S. C., the soil in the infested fields being very gravelly and in some places composed of almost pure sand. The injured plants, at the time of the discovery, were wilting, which made it appear as though they were suffering from want of moisture. At one place this species, together with *Diatraea zeacolella* Dyar, destroyed the greater part of a 7-acre field of corn.

In 1914 about 2 acres of corn (Pl. I, fig. 1), in a field on the State farm near Columbia, S. C., was damaged very severely by the larvæ. In many instances the plants were apparently killed outright when young, as in the case of the sorghum previously mentioned. Those that recovered were very much dwarfed, became one-sided, and gave rise to a number of suckers. The soil in this infested area is composed almost entirely of sand, while the rest of the field is a sandy loam.

Under date of October 7, 1914, Mr. Edmund H. Gibson, of the Bureau of Entomology, recorded larvæ of this species as injuring seriously corn in laboratory plats at Tempe, Ariz. Pulling up 15 stunted and withered corn plants, he found the larva in every stalk. Later in the month the larvæ were more abundant on corn and were also taken from sorghum sprouts and milo maize. On November 3 of the same year larvæ were collected from Johnson grass growing in a barley field, and about 70 per cent of the grass was injured, although the barley showed no evidence of injury.

During July and August, 1916, about 2 acres of sorghum in a field on the State farm near Columbia, S. C., was again practically laid waste by the ravages of these larvæ. The soil in this area also was of a sandy nature. Some of the badly infested plants were from 1 to 2 feet tall and without a central stem, as late as September, whereas plants uninfested were from 5 to 8 feet tall and in head.

Under date of August 19, 1916, Mr. H. L. Dozier, of the Florida Agricultural Experiment Station, informed the senior author that larvæ of this species were damaging cowpeas in plats on the station grounds.

The soil in these plats was of a sandy nature. He further stated that a report was received from Boca Grande, Fla., that 2 of 18 acres of cowpeas had been destroyed by this pest. Mr. R. N. Wilson, of the Bureau of Entomology, who was instructed to investigate this infestation more fully, confirmed Mr. Dozier's statement, young plants being injured by the larvæ boring into and upward in the stems, while in older plants the stems were girdled at or slightly below the ground. The result in both cases was that the injured plants wilted and died, although it was noted that in exceptional cases the plants, being vigorous, overcame the injury. Mr. Wilson further submitted a letter which had been received from Mr. Joseph Crews, farm demonstrator at Arcadia, Fla., stating that the "worms" injured cowpeas, Japanese cane, corn, and chufa. Cowpeas were damaged to some extent in the stiff black soil, but more serious damage was done in the sandy soil. This soil had all been well limed and heavily fertilized. Damage was done to Japanese cane planted in an old piece of land which was cleared years ago but had not been under cultivation for a number of years until the present. At least 90 per cent of the crop was damaged and the crop lost about 50 per cent in value.

While the increasing number of records of damage by this insect in the last few years is due in part to the fact that injury by it is more likely to be reported now than was the case years ago, it is also probable that the species is slowly modifying its habits to correspond with modern methods of agriculture and that, in the future, occasional outbreaks, perhaps more severe than any yet recorded, may be expected unless means are taken to check them in advance.

DESCRIPTIONS.¹

THE EGG.

The egg (fig. 2) is ovate, circular in cross section, 0.67 mm. in length and 0.46 mm. in diameter; greenish white when first deposited, pinkish in from 18 to 24 hours, an approximate Alizar crimson with a tinge of yellow at end of incubation period; strongly iridescent. Exochorion sculptured with shallow pits pentagonal to polygonal in outline. Endochorion apparently smooth.



FIG. 2.—The lesser corn stalk-borer: Egg. Greatly enlarged. (Original.)

LARVAL INSTARS.

First instar.—Length 1.7 mm. Head slightly bilobed, flattened, highly polished dark brown, width 0.23 mm., about as high as wide; clypeus triangular, 0.11 mm. high. Paraclypeal pieces not perceptible, region dusky; labrum pale, tips of mandibles reddish brown, not projecting; setæ 0.11 mm. long; antennæ pale, moderate. Cervical shield almost straight in front, much rounded behind, one not quite as wide as the head. Prespiracular tubercle bears 2 setæ, the upper of the two being the shorter; subventral tubercle also bears 2 setæ, the cephalad one being

¹ Descriptions by senior author. Measurements of all stages made from alcoholic material. That given for the length of larva in stage 5 is a little low on account of insufficient material on hand for a better average.



FIG. 1.—CORN INJURED BY THE LESSER CORN STALK-BORER IN A FIELD NEAR COLUMBIA, S. C., IN 1914. (ORIGINAL.)



FIG. 2.—INJURY TO SORGHUM BY THE LESSER CORN STALK-BORER NEAR COLUMBIA, S. C., IN 1913. (ORIGINAL.)

DAMAGE TO CORN AND SORGHUM BY THE LESSER CORN STALK-BORER (*ELASMOPALPUS LIGNOSELLUS*).

the shorter. Anal plate somewhat triangular, dusky. Body pale yellowish to yellowish green; posterior portion of each segment bright red to reddish brown on dorsum; whole dorsum of joint 5 of this color. These areas are joined by faint stripes, some little distance apart, of the same color, giving the larva a longitudinally striped as well as transversely banded appearance. Segments all slightly swollen, except last. Tubercles small; "iv-v" coalescent on joints 5-13, inclusive, below spiracle on joint 5, laterad and slightly cephalad of spiracle on joints 6-12, inclusive, directly laterad of "iii" in joint 13. Setae "iib" of joint 3 and "iii" of joint 12 0.25 mm. long, about twice as long as others. Abdominal segments except terminal crossed transversely through the middle by shallow grooves on dorsum. Thoracic feet pale, though somewhat dusky; abdominal prolegs all whitish.

Second instar.—Length 2.7 mm. Head slightly bilobed, flattened, highly polished, blackish brown, width 0.29 mm., clypeus 0.14 mm. high. Cervical shield concolorous with head, 0.26 mm. in width. Anal plate dusky. Body pale yellowish; transverse bands and stripes adjoining as in preceding stage. Tubercles "iib" of joint 3 and "iii" of joint 12 large, each supplied with a long seta as before; subprimaries present. Thoracic feet pale to dusky; abdominal prolegs same as venter of body, pale yellowish.

Third instar.—Length 5.7 mm. Head as in second instar except trifle paler, width 0.44 mm., a little wider than high; clypeus 0.20 mm. high; labrum pale amber, mandibles dark amber, almost black at tips; antennae pale amber at tips, otherwise pale whitish. Cervical shield large, darker than head, the anterior border extending somewhat over the head lobes, wider than head, width 0.54 mm., length 0.30 mm., corneous, polished. Body pale greenish white to pale yellowish green; transverse bands and connecting stripes reddish brown to brown, sometimes only greenish white between the stripes; tapering posteriorly. Thoracic legs dusky; abdominal prolegs pale yellowish green, same as venter.

Fourth instar.—Length 6.9 mm. Head slightly bilobed, polished dark brown, 0.61 mm., about two-thirds as high as wide; clypeus 0.25 mm. high; around base of spines pale. Cervical shield concolorous with head, width 0.89 mm., length 0.45 mm. Prespiracular tubercle large, somewhat corneous, dusky; subventral tubercle also dusky, normal. Body as in preceding stage except that venter is taking on deep green color; greenish white more conspicuous and breaking into the transverse bands, very deeply in some segments; stripes joining transverse bands wider than before. Thoracic legs and abdominal prolegs as before.

Fifth instar.—Length 8.8 mm. Head bilobed and polished as before, very dark brown black, width 0.89 mm., clypeus 0.32 mm. high, the paraclypeal pieces distinct, the sutures almost touching the beginning of the intersection point of the lobes on the vertex, whitish; labrum pale amber, mandibles amber, very dark at tips. Cervical shield darker than head, 1.02 mm. wide, 0.62 mm. long; on the meson is a pale stripe extending longitudinally from the posterior border to a point almost across the shield. Body as in preceding stage except that transverse bands are now at a point of being broken up, giving way to pale yellowish white color of the dorsum, the dark color being now confined chiefly to the longitudinal stripes, now almost continuous over the body but very irregular; in some specimens there is a whitish patch, ellipsoidal in outline, on the dorsum of joints 3 and 4; venter tinged with pale reddish. Thoracic legs and abdominal prolegs as in preceding stage.

Sixth instar.—Length 16.2 mm. (fig. 3). Head slightly bilobed, somewhat flattened, dark brownish black, highly polished, width 1.11 mm. Clypeus triangular, somewhat

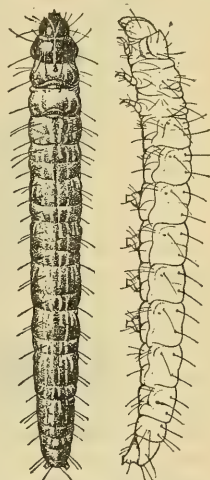


FIG. 3.—The lesser corn stalk-borer: Larva. Greatly enlarged. (Original.)

pale in the upper angle, extending over two-thirds of height of head (0.43 mm.). Paraclypeal pieces prominent, sutures converging at the beginning of intersection point of head lobes on vertex; setæ pale, stiff, pale around base; proximal parts of antennæ pale whitish, distal amber; labrum pale amber, width 0.32 mm.; mandibles dark red, black at tips. Cervical shield dark brown, width 1.49 mm., length 0.93 mm.; pale line on meson extending across the shield, coming to a point before, extending over head to intersection of lobes. Body Nile green, prevailing color on the dorsum greenish white, which almost breaks up completely the dark brown transverse bands; longitudinal stripes conspicuous, dark brown, somewhat broken. Tubercles "ia" and "ib" of joint 3 small, setæ short, "ia" and "iib" small, seta long; "ia" and "ib" of joint 4, small, seta short, "ia" and "iib" small, seta long, caudad of latter is dusky patch, somewhat polished; on joints 3 and 4 "iii" is caudo-laterad of "iib," distant, "iv" is cephalad and slightly laterad of "iii," distant, "v" cephalo-laterad of "iv," well separated; "iv-v" is coalescent on joints 5 to 13, inclusive, arrangement as before; on joint 13 "vi" is near "v"; on joints 12 and 13 "ii" is much nearer meson than "i," on joint 11 "i" and "ii" arranged in form of square. All segments slightly swollen except last two; transverse grooves prominent. Thoracic legs dusky; abdominal prolegs pale.



FIG. 4.—The lesser corn stalk-borer: Pupa. Greatly enlarged. (Original.)

PUPA.

The pupa (fig. 4) when freshly formed is pale green, yellowish on abdominal segments; later brown and just preceding emergence of adult uniform black; lustrous; delicate; length 8.1 mm., width 2 mm. Spiracles ellipsoidal, prominent, except on joint 12, obsolete. Dorsum of terminal segment has slight elevation or hump which slopes abruptly posteriorly and forms the obtuse tip. Anterior portion of this elevation corneous, rugose, and black. At tip is a row of six hooked spines arranged transversely, about 0.17 mm. in length. Tip of the male pupa is rounded, that of the female pupa irregular. Other sexual differences in pupal stage shown in figure 5, *a* and *b*. Abdominal segments 1 to 7, inclusive, densely and finely pitted on dorsum, very abundant and scattered almost over whole surface of first four segments, scant and restricted to anterior border of last three.

COCOON.

The cocoon is cylindrical, compact, 15.9 mm. in length, and 5.9 mm. in diameter, oval in outline, frequently supplied with exit tube at an angle of about 145°; 23.9 to 30 mm. in length and 4 mm. in diameter; lined throughout on inside very smoothly with silk and covered without with sand and dirt particles. (Pl. II, figs. 3 and 4.)

ADULT.¹

Expanse 17–22 mm. Head brown to blackish. Labial palpi erect, not recurved; somewhat longer in the male than in the female and more slender, heavily scaled, lying close together on the shining crest which is hollowed out for them; somewhat clavate toward the tip, end member very short, about one-eighth the middle; groove for the pale papillary tufts reaching almost to the apex and very deeply impressed. Basal segments pale gray outside, within bearing a longitudinal white stripe which broadens somewhat at the end of

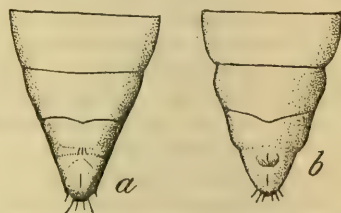


FIG. 5.—The lesser corn stalk-borer. Comparison of terminal segments of male and female pupæ showing sexual differences: *a*, Female; *b*, male. Greatly enlarged. (Original.)

¹ Compiled from descriptions of Zeller and Hulst by the junior author.

the second and beginning of the last segment. Maxillary palpi pencil-tufted. Proboscis long, strong, scaled. Ocelli present. Antennæ brownish, simple, bent and expanded above the base, with a heavy tuft of scales in the bend in the male; in the female more slender and without the tuft. (Fig. 6.)

Thorax ochre-brown to blackish. Legs brownish gray, darker on the outside; tarsal segments bright yellow. Forewings very narrow, much elongated, 8-9 mm. long; distal margin oblique, posterior margin waved; in male (fig. 6, *a*) ochre-brownish on posterior margin from base out, with a poorly defined median stripe of ochre-brownish reaching almost to distal margin; remainder of margin varying from a narrow edging of brown to a complete covering of wing with blackish to plumbago; disk yellow-ochreous to reddish; on subdorsal vein slightly before middle where posterior margin begins to darken lies a dense brown dot marking position of first transverse line; diagonally outwards above it upon median vein is a smaller dot and beyond a more prominent one on cross vein; both lie in the bright median space but close to yellowish-brown shading of anterior margin; distal margin marked by row of black confluent dots within which is indistinct grayish stripe dusted with whitish atoms; within this in the dark color of surface appears beginning of second cross line very close to distal

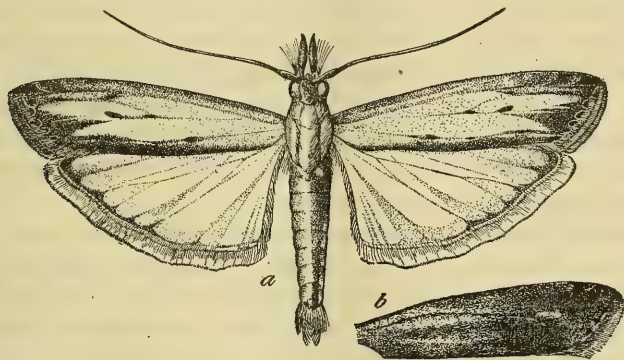


FIG. 6.—The lesser corn stalk-borer: *a*, Male moth; *b*, forewing of female moth. Greatly enlarged. (Original.)

margin and most apparent on anterior margin; fringes brownish gray, beneath shining brownish gray; in the female (fig. 6, *b*) markings are the same but generally darker than in male; dot on the subdorsal vein enlarged but not prominent, dot on cross vein somewhat more distinct. Hind wings white, pellucid, somewhat grayish or brownish along anterior and distal margins and at apex shading back into the wing for a greater or less width; fringes whitish, brownish toward apex and bearing a faint yellowish line paralleling margin; beneath along anterior margin browner than above. Venation: Forewings, eleven veins, 4 and 5 separate, 10 separate; hind wings, 2 more or less distant from angle, 4 and 5 stemmed, 6, 7, and 8 stemmed, cell rather short.

Abdomen yellowish to fuscous, darker in female; terminal tuft of male yellowish at the end and in the middle, gray laterally, darkening toward end; of female yellowish. Male genitalia: Uncus longer, more slender than usual in related genera, bifid at base; these parts arched; the spine long, harpes broad with long hairs along upper edge forming somewhat of an anal tuft; a strong bent spine at base; lower plate conical, within entrance a long, slender, bent spine; last segment of abdomen beneath with two tufts of hair.

SEASONAL HISTORY.

OVIPOSITION.

Eggs of this species have not been found in the field; but, judging from the results obtained from rearing, they are probably deposited on the stems of plants, in the axils of the leaves, or on the ground at or near the bases of the stalks. The larvæ upon hatching crawl to the stalks and begin feeding.

In rearing cages, the eggs are deposited generally on the cheesecloth which covers the lantern globe. Sometimes, however, they are deposited on bits of grass leaves or stems, pieces of cloth or other loose material placed in the bottom of the cage, on the stem of grass placed in the cage as food or, not at all infrequently, upon the cotton which holds the sprig of grass in place. Most of the eggs deposited on the cloth top are pushed through the mesh of the cloth by the female and are found on the upper side of the cloth, appearing as though they were deposited from without. Eggs are placed singly as a rule, though sometimes two or three *en masse* may be found glued securely together. In such cases they lose their individual rotundity and flatten out somewhat at points at attachment. A mucilaginous substance secreted by the female, which hardens after exposure to the air, glues the eggs firmly to the object.

The females begin to oviposit shortly after dusk and continue until the early hours of the morning. The majority of the eggs are deposited during the forepart of the night and it is probable that all of them are laid at this time under field conditions. No eggs are deposited during the day or in bright light at night. Oviposition will take place, however, in diffused light, although not as many eggs will be deposited as in total darkness.

EFFECT OF TEMPERATURE ON OVIPOSITION.

Oviposition did not take place when the temperature fell much below 80° F. Two cages containing a number of females and males were kept under normal conditions; three others, also supplied with a number of moths of both sexes, were kept in a room the temperature of which rose to somewhere between 80 and 90° F. during the day and fell gradually, reaching approximately 80° F. by early evening and practically normal by morning, as the windows were kept open all night. Eggs were obtained in all the cages kept in the room, all of them being deposited during the early part of the evening. No eggs were obtained in the cages kept under normal conditions. The same type of cage was used in both cases, consisting of a flower-pot surmounted by an ordinary lantern globe, the top of which was closed with a bit of cheesecloth held in place by a rubber band.

TABLE I.—*Incubation records of eggs of Elasmopalpus lignosellus obtained from one female at Columbia, S. C., 1913.*

Deposited.		Hatched.		Incubation period.
Date.	Number of eggs.	Date.	Number of eggs.	
Aug. 28.....	50	Aug. 31.....	50	<i>Days.</i> 3
Aug. 29.....	57	Sept. 1.....	57	3
Aug. 30.....	40	Sept. 2.....	40	3
Aug. 31.....	49	Sept. 3.....	49	3
Sept. 1.....	36	Sept. 4.....	36	3
Sept. 2.....	30	Sept. 5.....	30	3
Sept. 3.....	26	Sept. 7.....	26	4
Sept. 4.....	17	Sept. 8.....	17	4
Sept. 5.....	7	Sept. 9.....	7	4
Sept. 6.....	3	Sept. 9.....	3	3
Sept. 7.....	4			
Total.....	319			
Average.....				3.16

TABLE II.—*Incubation period of eggs of Elasmopalpus lignosellus deposited during 1914 and 1915 at Columbia, S. C.*

Deposited.		Hatched.		Egg stage.
Date.	Number of eggs.	Date.	Number of eggs.	
Aug. 31, 10 p. m. to 11 p. m.....	1	Sept. 5, 7 p. m.....	1	<i>Hours.</i> 116-117
Aug. 31, 11 p. m. to 12 m.....	14	Sept. 5, 8.30 p. m.....	12	116.5-117.5
Sept. 1, 7 p. m.....	1	Sept. 6, 8 a. m.....	2	128.5-129.5
Sept. 1, 12 m.....	30	Sept. 6, 9 a. m.....	1	110
Sept. 9, 8 p. m.....	2	Sept. 5, 8.30 p. m.....	14	92.5
Sept. 9, 8 p. m. to 10 p. m.....	23	Sept. 6, 8 p. m.....	16	116
Sept. 2, 9 p. m.....	66	Sept. 12, 10 p. m.....	2	74
		Sept. 12, 10 p. m.....	21	70-72
		Sept. 12, 12 m.....	2	74-76
		Sept. 6, 9 a. m.....	66	84
Sept. 5.....	11	Sept. 9.....	11	<i>Days.</i> 4
Sept. 4.....	36	Sept. 8.....	36	4
Sept. 10.....	53	Sept. 13.....	53	3
Sept. 13.....	24	Sept. 18.....	24	5
June 23.....	27	June 26.....	27	3

LENGTH OF INCUBATION PERIOD.

From Tables I and II it will be seen that the egg stage varies from three days in the summer time to five days in early fall, being influenced greatly by temperature conditions. In late fall, eggs were obtained that required from six to eight days to hatch.

TABLE III.—Number of eggs deposited by 1 female of *Elasmopalpus lignosellus* in 1 day and during life, at Columbia, S. C., 1915.

Cage 15-1112.		Cage 15-1113.		Cage 15-1114.	
Date of oviposition.	Number of eggs.	Date of oviposition.	Number of eggs.	Date of oviposition.	Number of eggs.
June 15.....	73	Sept. 2-3.....	25	Aug. 31.....	15
June 16.....	11	Sept. 4.....	36	Sept. 1.....	31
June 17.....	73	Sept. 5.....	11	Sept. 2-3.....	38
June 19.....	61	Sept. 6.....	5	Sept. 4-5.....	19
June 21.....	27	Sept. 8.....	9	Sept. (?).....	60
June 22.....	39	Sept. 9.....	7	Sept. 9.....	22
June 23.....	27	Sept. (?).....	20	Sept. 10.....	3
June 24.....	15	Sept. 10.....	9	Sept. 11.....	3
June 25.....	6	Sept. 11.....	12	Sept. 12.....	1
June 26.....	4				
June 28.....	6				
Total.....	342		134		192
Average per day.....	24.43		(?)		(?)

Cage 15-1115.		Cage 15-1116.		Cage 15-1117.	
Date of oviposition.	Number of eggs.	Date of oviposition.	Number of eggs.	Date of oviposition.	Number of eggs.
Sept. 10.....	53	Sept. 8.....	56	Sept. 13.....	24
Sept. 11.....	56	Sept. 9.....	35	Sept. 14.....	55
Sept. 12.....	38	Sept. 10.....	34	Sept. 15.....	12
Sept. 13.....	34	Sept. 11.....	33		
Sept. 14.....	1	Sept. 12.....	28		
Sept. 15.....	9	Sept. 14.....	8		
Sept. 16.....	2				
Sept. 17.....	4				
Total.....	197		194		91
Average per day.....	24.63		27.71		30.30

NUMBER OF EGGS DEPOSITED BY ONE INDIVIDUAL.

The number of eggs deposited by one individual under laboratory conditions varies (as will be seen by referring to Table III) from 91 to 342, with an average of 190. The small number deposited in Cage 15-1117 was probably due to premature death of the female.

The number of eggs deposited by one individual in any one day varies from 1 to 73. The daily average computed from the daily average of the four cages in Table III is about 26.77 eggs.

In two other experiments conducted in July, 1914, 188 eggs were obtained in one cage and 311 eggs in the other.

PROCESS OF HATCHING.

Shortly before the larva is ready to emerge it can be seen very distinctly through the semitransparent shell. The brown-black head and the pinkish markings on the segments especially are conspicuous. The larva occupies a curled position inside of the shell, with its head resting on the ultimate and penultimate segments of the body. Just preceding emergence a wavelike rhythmic motion is seen, starting at the head and continuing from segment to segment slowly to the end of the body, after which the larva moves its head about and with its mandibles makes an incision large enough for it to pass through. This takes about five minutes. The larva then usually rests a few minutes, after which it begins to draw itself out of the shell.

NUMBER AND LENGTH OF INSTARS AND LENGTH OF LARVAL LIFE.

The number of instars and their length, as well as the total length of the larval life, are extremely variable, as will be noted by referring to Tables IV, V, and VI. These variations are due in part to differences of temperature. During the summer months the larvæ may molt four or five times and in fall five or six, making from five to six instars for the former and six to seven for the latter. The seventh instar in such instance resembles the sixth in color pattern and size. The second instar and sometimes the third is somewhat longer than the first during the summer months. In fall, however, the first instar is longer than any of the others, except the last one, or the one just preceding pupation, which is generally also the longest during the summer months.

The length of the life of the larva is somewhat dependent upon the number of instars. The larger the number of instars the larva undergoes, the longer the period it will take in reaching maturity, as is brought out by comparing the averages of the instars in Tables IV, V, and VI. In Table IV the larvæ having five instars reached maturity in 374.5 hours, while those having six instars reached maturity in 406.33 hours. In Table V those having five instars reached maturity in 397 hours, as compared to 453 hours for the six-instar larvæ. In Table VI the six-instar larvæ required 842 hours while the seven-instar larvæ required 906 hours to reach maturity.

The larvæ may reach maturity in the short period of 13.8 days, but generally in about 16.8+ days, during the summer months. However, one larva required as many as 20.8+ days to reach maturity. In fall, when temperatures are low, this period is considerably lengthened, varying from a minimum of 22.0+ to a maximum of 41.6 days.

TABLE IV.—*Number of instars, their length, and length of larval life of Elasmopalpus lignosellus during the months of June and July, 1914, at Columbia, S. C.*

Number of tube.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.	Length of larval life.
	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>
1.....	56	60	48	96	144	.....	404
2.....	44	36	48	60	144	.....	332
3.....	44	36	60	48	72	144	404
4.....	44	36	48	60	84	144	416
5.....	44	36	48	60	48	172	408
6.....	56	60	48	72	172	.....	408
7.....	44	36	48	84	144	.....	356
8.....	44	36	60	72	84	108	404
9.....	44	36	48	84	72	120	404
10.....	44	36	48	60	84	132	404
11.....	44	48	36	60	72	144	404
12.....	44	48	36	60	84	156	428
13.....	44	48	36	60	84	156	428
14.....	44	36	48	60	48	120	356
15.....	44	36	60	72	144	.....	356
16.....	44	36	60	72	120	.....	332
17.....	44	36	48	60	84	144	416
18.....	44	36	60	72	72	120	404
19.....	56	48	84	84	180	.....	452
20.....	44	36	48	84	144	.....	356
Average.....	45.8	40.8	50.5	69	104	138.3	393.6

TABLE V.—*Number of instars, their length, and length of larval life of Elasmopalpus lignosellus, during the month of August, 1915, at Columbia, S. C.*

Number of tube.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.	Length of larval life.
	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>
15-771.....	69	60	60	72	120	.....	381
15-773.....	81	36	72	72	144	.....	405
15-774.....	45	72	48	72	120	.....	357
15-775.....	69	72	72	48	72	96	429
15-776.....	69	72	72	48	72	120	453
15-777.....	69	60	60	72	72	120	453
15-786.....	69	72	48	72	24	168	453
15-788.....	81	60	72	72	120	.....	405
15-790.....	69	60	60	72	120	.....	381
15-791.....	69	72	48	72	72	144	477
15-795.....	93	60	60	72	120	.....	405
15-797.....	69	72	48	72	120	.....	381
15-925.....	69	48	48	72	120	.....	357
15-926.....	81	48	60	72	168	.....	429
15-927.....	69	48	48	72	144	.....	381
15-929.....	69	48	72	72	120	.....	381
15-933.....	81	60	48	72	240	.....	501
Average.....	66	59.6	58.6	69	115.8	127.6	413.5

TABLE VI.—*Number of instars, their length, and length of larval life of Elasmopalpus lignosellus, during the months of September and October, 1914, at Columbia, S. C.*

Number of tube.	First instar.	Second instar.	Third instar.	Fourth instar.	Fifth instar.	Sixth instar.	Seventh instar.	Length of larval life.
	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Hours.</i>
1.....	209	72	108	156	120	108	144	927
2.....	153	84	72	96	192	120	168	885
3.....	165	108	204	132	48	144	.....	799
4.....	165	84	252	96	72	288	.....	957
5.....	117	156	108	84	84	288	.....	837
6.....	129	120	144	72	96	216	.....	777
Average.....	156.3	104	148	106	102	194	156	863.7

DURATION OF THE MOLTING PERIOD.

During the summer months the time required for the larvæ to molt varies from 12 to 24 hours in all the instars and during the fall from 12 to 26 hours and sometimes 48 hours. The majority of the larvæ in fall require only 24 hours. Generally a longer time is required in the last instars than in the first ones.

DESCRIPTION OF ECDYSIS.

The larva when about to cast its skin becomes pale, sluggish, and usually remains motionless in tunnel or tube unless disturbed, and even then it is not as active as normally. The first real indication that molting has commenced is the appearance of a pale whitish patch in the region of the neck. This patch is the outer conjunctival layer which, having been loosened, is being unfolded to accommodate the growing larva. This patch becomes more and more evident as molting progresses. The eyes at this time can be seen through the semitransparent conjunctival layer, appearing a little distance back of the head mask. The outer layer of the cuticle, having been loosened throughout, ruptures immediately back of the head mask, first on the venter, then rapidly extending laterally and dorsally. The larva with wavelike rhythmic motions gradually draws itself out of the old cuticular layer. Just at the point when the last joint is being extricated the larva bears down with the head and frees itself from the mask.

FEEDING HABITS OF THE LARVA.

The larva of the species, as its common name would indicate, has a habit of boring or tunneling into the stems of growing plants (Pl. III, fig. 3) and feeding within. This manner of feeding is especially characteristic where young corn and sorghum plants are attacked. The larvæ in such cases tunnel into the stalks at or slightly below the surface of the ground, through and sometimes up the heart for a distance varying from 1 to 2 inches. The bud leaves of such affected plants die, having been severed from the main plant; Plate III, figure 2, shows the appearance of such a plant. The bud leaves dry up and wither away. Some of the plants may survive, but such plants remain in a dwarfed condition or become deformed and one sided.

Injury to corn in this manner resembles closely the work of the southern corn rootworm (*Diabrotica 12-punctata* Oliv.); however, *E. lignosellus* is an upland species, being found only in the driest of soils, while the corn rootworm breeds generally in the moist lowlands.

In older corn and sorghum, as well as in cowpeas, the damage consists primarily in the girdling of the stems at or slightly below the surface of the ground, but the larvæ also tunnel into the stems,

thereby weakening them to such an extent that very little pressure is required to break them off, and frequently infested plants break off at this point when attempts are made to pull them up.

Cowpea plants have been found almost completely cut in two, at a point near or slightly below the surface of the ground, by the larvæ girdling the stem, while in other cases the larvæ were found tunneling into the stems as in the case of corn and sorghum.¹

It is seldom that larvæ are found in the tunnels of the plants upon which they feed, but more often in specially constructed tubes which lead away from the entrance to the tunnel in the stalk, lying even with or slightly beneath the surface of the ground or sometimes curved around the stems. Plate II, figures 1 and 2, shows the tubes attached to the stems at the entrance to tunnels. These tubes are often 2 inches or more in length and have a number of side galleries or chambers (Pl. III, fig. 1). They are composed of particles of sand and dried excrement of the larvæ spun together with silk. They are generally rather delicate and fall to pieces unless handled with great care. The larvæ apparently use these tubes as a means of retreat when disturbed while feeding.

In young corn and sorghum not more than two larvæ have been found feeding on one plant, each from within a separate tube, and in cowpea plants never more than one. In older corn and sorghum as many as 6 larvæ have been found feeding at one time on the same plant and 13 cocoons taken from the surrounding soil. Dr. Forbes (24) reports that as many as 13 larvæ have been found feeding on a single corn plant.

In our rearing cages larvæ were fed cowpea leaves in test tubes and jelly glasses. During the first and second instars the larvæ have a habit of partially skeletonizing the leaves, devouring the epidermis of one side and the mesophyll, leaving the epidermis of the other side intact. They construct on the leaf delicate tubelike coverings made up of dried excrement spun with silk and feed from under this covering. After the second instar the larvæ begin to eat the leaves, perforating them and devouring all except the mid-veins. They persist in skeletonizing the leaves even when almost mature, and this is especially noticeable when given leaves that are somewhat tough or whose tissues have hardened. The boring habit (Pl. III, fig. 3), so characteristic of the work of the larvæ in stalks, was demonstrated even while the larvæ were feeding upon leaves, the larvæ even in their earlier stages boring into the larger veins of the leaves and petioles and constructing tubes leading away from the entrance to the tunnel. This habit was discontinued in the last stages, the larvæ feeding as do those of most Lepidoptera.

¹ Dr. Chittenden (22) makes mention of this method of feeding and illustrates it with a figure.

ACTIVITY OF THE LARVA.

The larvæ of this species, while very active, even when quite young, are much more so as they become older. They have a habit, when disturbed, of skipping and jumping about, an acrobatic feat which lasts from one to four seconds, during which time they go through all kinds of contortions, frequently throwing themselves clear of the surface upon which they have been placed. Just how this is accomplished is not definitely known, as it is done almost too quickly for the eye to follow. However, they appear to bear down with the head and posterior end of the body at the same time, with such force that the impact throws them into the air. On account of this skipping habit the larvæ are frequently but erroneously termed "skippers."

That the larvæ are resistant to rough treatment is indicated by the following ordeal through which one was put by the junior author in an effort to photograph it. It was chloroformed for 15 minutes and, being then still somewhat active, was put into 80 per cent alcohol for 15 minutes more. The next morning it had revived and, except for a loss in the brilliancy of its coloring due perhaps to its enforced fast, was as active as before.

The larvæ in all stages spin a silken thread wherever they go, and the younger ones readily suspend themselves by it.

LENGTH OF PUPAL STAGE.

The length of the pupal stage varies considerably, as will be seen from Table VII, temperature conditions having a great effect upon the length of this stage. This stage varies from 7 to 11 days in July, from 7 to 10 days in August, from 8 to 18 days in September and October, and from 19 to 21 days in October and November. The general average from the records of Table VII is 10.16 + days.

It should be stated that the records obtained during the fall of the year are approximate, as it has been found that the larvæ, upon entering the pupation tubes, sometimes do not transform immediately.

TABLE VII.—*Length of pupal stage of Elasmopalpus lignosellus. Records obtained at Columbia, S. C., in 1915.*

Number of individuals.	Date of—		Days.	Sex.	
	Pupa- tion.	Emer- gence.			
	1913.	1913.			
1	Sept. 29	Oct. 16	17	.....	Male.
1	Sept. 30	...do....	16	Female....	
	1914.	1914.			
2	July 8	July 17	9	...do....	Do.
1	July 9	...do....	8	...do....	
1	...do....	July 18	9	.....	
1	...do....	July 20	11	.....	
4	July 11	...do....	9	2 females..	1 male.
1	July 12	...do....	8	Female....	
1	July 13	July 21	8	...do....	
1	...do....	July 20	7	.....	
	1915.	1915.			
1	Aug. 16	Aug. 25	9	.....	Male.
1	Aug. 17	...do....	8	Female....	
1	Aug. 18	Aug. 27	9	.....	Do.
1	...do....	Aug. 28	10	.....	Do.
1	Aug. 20	...do....	8	Female....	
1	...do....	Aug. 30	10	.....	Do.
1	Aug. 21	Aug. 28	7	.....	Do.
1	...do....	Aug. 29	8	.....	Do.
1	...do....	Aug. 30	9	.....	Do.
1	...do....	Aug. 31	10	.....	Do.
2	Aug. 23	...do....	8	Female....	Do.
3	Aug. 29	Sept. 6	8	2 females..	1 male.
1	...do....	Sept. 7	9	Female....	
1	...do....	Sept. 9	11	.....	Male.
1	Aug. 30	Sept. 7	8	Female....	
1	Sept. 24	Oct. 4	10	.....	Do.
1	Sept. 25	Oct. 6	11	.....	Do.
1	...do....	Oct. 9	14	Female....	
1	Sept. 27	Oct. 7	10	.....	Do.
1	Sept. 28	Oct. 6	8	.....	Do.
1	...do....	Oct. 7	9	.....	Do.
2	...do....	Oct. 9	11	Female....	Do.
1	...do....	Oct. 12	14	...do....	
1	...do....	Oct. 14	16	...do....	
1	...do....	Oct. 15	17	...do....	
1	Sept. 29	...do....	16	...do....	
1	Sept. 30	Oct. 16	16	...do....	
2	Oct. 1	...do....	15	...do....	Do.
1	Oct. 4	Oct. 18	14	...do....	Do.
1	Oct. 6	...do....	12	...do....	
1	Oct. 7	Oct. 19	12	...do....	
1	...do....	Oct. 20	13	...do....	
1	...do....	Oct. 23	16	...do....	
1	...do....	Oct. 25	18	...do....	
1	...do....	Oct. 28	21	...do....	
1	Oct. 13	Nov. 1	19	.....	Do.
1	...do....	Nov. 8	26	Female....	
1	Oct. 18	...do....	21	...do....	
2	Oct. 20	Nov. 10	21	2 females..	
59	.....	.....	10. 16+		

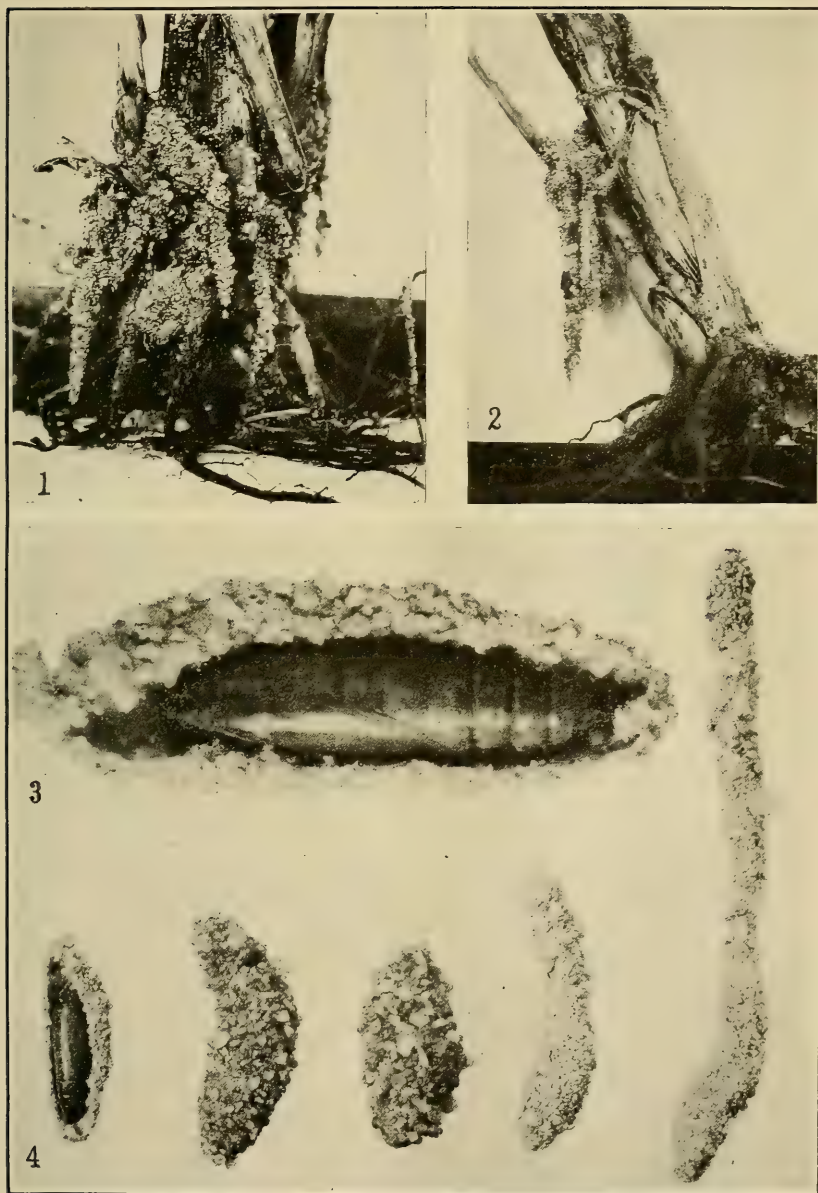
Average length of pupal stage, 10.16+ days.

Maximum length of pupal stage, 21 days.

Minimum length of pupal stage, 7 days.

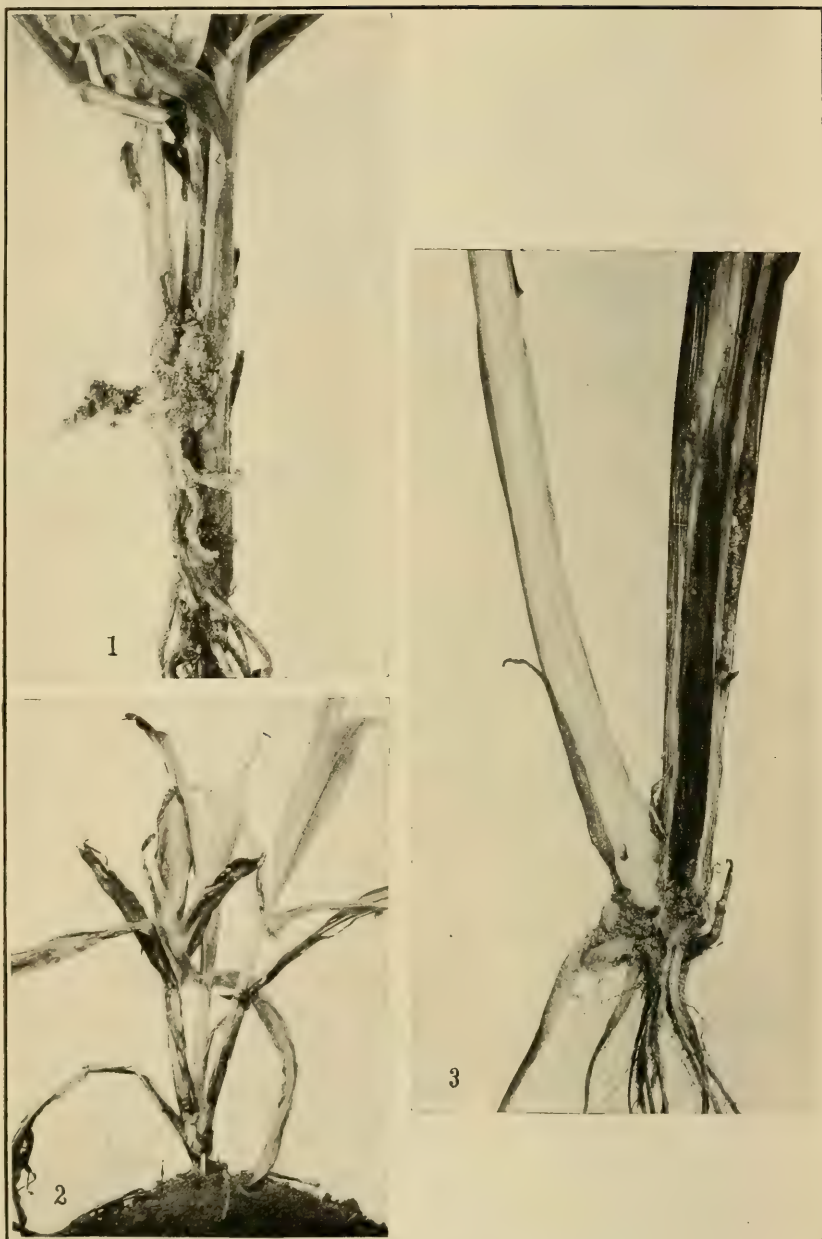
MATING.

Moths of this species usually mate the second day after emergence from pupæ in the summer time, and in the fall this period is somewhat lengthened. Mating probably takes place at night, although the moths have never been seen in coitu. A pair were found in copula in a cage in the morning and upon examination it was discovered that they were unable to disconnect themselves.



FEEDING TUBES AND COCOONS OF THE LESSER CORN STALK-BORER.

FIGS. 1, 2.—Feeding tubes attached at entrance to tunnels, at base of sorghum stalks. FIG. 3.—Cocoon opened, showing pupa *in situ*. FIG. 4.—Cocoons, with and without exit tubes. (Original.)



DAMAGE TO SORGHUM BY THE LESSER CORN STALK-BORER.

FIG. 1.—The many-branched feeding tube attached at entrance to tunnel, at base of sorghum stalk. FIG. 2.—Sorghum severely damaged by stalk-borers, as shown by the dead bud leaves. FIG. 3.—Stem sectioned to show the borer tunnel within. (Original.)

ACTIVITY OF THE MOTHS.

The moths are very active during the night. They are positively phototropic to bright light and even react positively to diffused light. This probably accounts for the fact that copulation and oviposition were not observed, for as soon as cages were placed in light sufficient for observation the moths became restless and began to roam around in the cages.

LENGTH OF LIFE OF ADULTS.

The length of life of the adults of this species varied from five to eighteen days in the rearing cages, as is shown in Table VIII. The average duration of this period is approximately the same in both sexes. Adult moths confined in cages and supplied with food (sugar sirup) lived longer than when deprived of it.

TABLE VIII.—Length of life of moths of *Elasmopalpus lignosellus*, at Columbia, S. C.

Male.				Female.			
No.	Emerged.	Died.	Days.	No.	Emerged.	Died.	Days.
1.....	June 15	July 3	18	1.....	June 15	July 3	18
2.....	July 17	July 27	10	2.....	July 17	July 27	10
3.....	July 17	July 27	10	3.....	July 17	July 28	11
4.....	July 19	July 28	9	4.....	Aug. 22	Sept. 9	18
5.....	Aug. 30	Sept. 13	14	5.....	Aug. 30	Sept. 13	14
6.....	Aug. 30	Sept. 16	17	6.....	Aug. 30	Sept. 12	13
7.....	July 17	July 24	7	7.....	Sept. 10	Sept. 15	5
Average.....			12.1	Average.....			12.7

POLYGAMY.

Experiments were conducted to ascertain whether polygamy exists among the moths of this species. The moths that were used in these experiments emerged from pupæ which had been placed in individual tin boxes, and there was absolutely no chance of their having mated upon issuing, before being placed in the rearing cages.¹

The male, after the death of the female (Cage 15-1113) with whom he had mated and from whom 134 eggs were obtained, was placed with a freshly issued female (Cage 15-1117). From this female 91 eggs were obtained. All of the eggs that were obtained in both of these cages were fertile.

In another cage, the male, which had mated with a female (Cage 15-1114) and from whom 192 fertile eggs resulted, was placed (Cage 15-1116) with a virgin female. From this female 194 fertile eggs were obtained.

¹ All of these cages are recorded in Table III.

LIFE CYCLE.

The life cycles of the generations (Table IX) during summer are considerably shorter than those of the fall of the year and possibly shorter than that of the spring generation. The spring generation has not been reared but probably has about the same cycle as the fall generation. They are about as follows:

TABLE X.—Duration of the spring and fall generations of *Elasmopalpus lignosellus* at Columbia, S. C.

Period or stage.	Summer broods.	Fall broods.
	<i>Days.</i>	<i>Days.</i>
Time elapsing between emergence and oviposition.....	2	2.5
Egg stage.....	3.5	5.6
Larval stage.....	24	36
Pupal stage.....	9	21
Total.....	38.5	64.6

By comparing the two cycles it will be noticed that the time required for the insect to pass through the cycle during the summer months is only about 6.2 days more than one-half of the time required in the fall of the year.

NUMBER OF GENERATIONS.

There are probably four generations of this species in the latitude of Columbia, S. C., although it has not been reared continuously for one whole year to verify this. However, three complete generations were reared from the middle of June to the middle of October in 1913.

Some of the pupæ of the last generation gave rise to moths, while the remainder died during the winter. Some of the larvæ of this last generation, not pupating in the fall, died also during the winter, apparently from the lack of suitable food and from being kept under abnormal conditions. Otherwise they possibly would have completed their growth, pupated, and given rise to moths early in the following spring (1914).

Our collection in the spring of 1915 would seem to substantiate this. Larvæ nearly full grown were found for the first time on corn in the field during the first week in June, thus rendering it probable that the eggs producing these larvæ were placed when the corn was up, by the moths issuing from pupæ in the early spring, as the field in which they were found was winter plowed and freed from rubbish and grass, making it impossible for these larvæ to have wintered over under these conditions.

WINTERING.

In the latitude of Columbia, S. C., this species apparently passes the first part of the winter as a larva and the latter part as a pupa and possibly adult, although it has not been possible to verify this absolutely by rearing experiments.

Larvæ have been found in the field, in their burrows in the stalks, as late as the middle of November, after which time none could be found. Repeated efforts were made at various times during winter to find pupæ, and one cocoon containing a pupa was found in January which, unfortunately, died. This pupa probably would have changed early in the spring to an adult.

According to the experiments of the writers in 1915, larvæ pupating in the fall did not winter as such but gave rise to moths in early winter. These moths died within a short time, which circumstance would seem to indicate that this species does not winter in the adult stage. Larvæ have been kept alive in rearing cages under outdoor conditions up to January, at which time they died, apparently from being kept in closed receptacles, which was very favorable for the development of a fungus which killed them.

In Arizona the species probably passes the winter in the larval stage, judging from the fact that larvæ in all sizes were found as late as November 3 at Tempe, Ariz.

REARING METHODS.

In rearing the larvæ of this species a number of different types of cages were used, such as the ordinary "pot cage" surmounted by a lantern chimney covered with cheesecloth, or with a celluloid cylinder covered with cheesecloth. None of these types of cages gave complete satisfaction, for the reason that they could not be made tight enough and the larvæ, being very restless, are ever on the alert to find an opening through which they may escape.

Tin salve boxes and the ordinary low-type jelly glass with tin cover proved the most satisfactory of all cages. In rearing these larvæ, a small quantity of sand was placed in the bottom of each and kept moistened. These containers were kept supplied with fresh cowpea leaves and a number of larvæ were reared in each receptacle.

To obtain eggs, a cage, consisting of a 6-inch flowerpot saucer, lantern chimney covered with cheesecloth, and a bottle containing a small sorghum plant, in water, was employed with success.

In making a study of the different instars, small test tubes, used in bacteriological experiments, were found to be the most practical, on account of the convenient size and also because observations could be made without removing specimens.

NATURAL ENEMIES.

According to observations, the lesser corn stalk-borer apparently suffers very little from natural enemies. This condition is undoubtedly a result of the excellent protection afforded the larvæ at all times, both while feeding in their burrows and while resting in their tubes. One parasite, a hymenopteron, determined as *Neopristomerus* sp., has been reared in the laboratory at Columbia, S. C. This parasite emerged September 1, 1914, from a larva collected at Columbia, S. C.

Another parasite was reared by R. N. Wilson at Gainesville, Fla., September 11, 1916, which was determined by Mr. A. B. Gahan as *Orgilus laeviventris* Cress. Mr. Gahan believes it probable that the parasite of *Elasmopalpus lignosellus* recorded by Chittenden (18) as *Orgilus mellipes* Say was in reality *laeviventris*.

METHODS OF CONTROL.

The ravages of this insect can be reduced markedly if not entirely controlled by progressive methods of farming. Infested fields should be plowed very late in fall or early winter, after they have been freed from all remnants and waste material. The borders and terraces of the field should be gone over with a harrow to stir up the ground. This breaks up the winter quarters of pupæ and causes them to perish.

The practice of cleaning up and working these waste places is not only an excellent one for the eradication of this species but also contributes to the destruction of many other noxious insects that chance to be hibernating therein; and as usually very little attention is given to the practice of clean cultural methods and the cleaning up of such waste places, the importance of such methods can not be overemphasized.

In regions where this insect remains more or less active throughout the winter, it is advisable to plow out and destroy the infested stubble in case of corn, sorghum, etc. In all other cases fall plowing and thorough working of the ground are to be recommended.

It is also of great importance that the sandy areas of the fields be made as rich as possible. A thorough application of fertilizer should be made in order to stimulate plant growth and make the plants more resistant to the attacks of this insect.

Where it is necessary to plant corn, sorghum, and allied crops in fields subject to infestation, it is advisable to make such plantings as early in the season as possible, thus enabling the plants to get a good start before the insect begins its depredations.

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PROFESSIONAL PAPER

July 27, 1917

A FIRST-YEAR COURSE IN HOME ECONOMICS FOR
SOUTHERN AGRICULTURAL SCHOOLS.¹

By LOUISE STANLEY, *Professor of Home Economics, University of Missouri.*

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INTRODUCTION.

This bulletin outlines a course of study in home economics for southern high schools. It emphasizes the connection between such instruction and actual home experience and the danger arising from formal methods of presentation. It calls attention to underlying general principles and applies them in a typical course of study, which, while based on southern conditions, is applicable in other communities.

The aim of any course in home economics is to make the girl a better home maker. By teaching her how to do, and the reasons why, and as well by giving insight into the fundamental importance of home making such instruction transforms housework from drudgery into an honored profession. In the average home two industries stand out—sewing and cooking—and there has been a tendency to limit home economics instruction to them. If interpreted broadly to include their economic and hygienic relations, cooking and sewing do furnish the basis of a well-rounded course; but they should be supplemented by other subjects necessary for the home maker. Knowledge of the homes of her community will best assure to the teacher suitable subject matter and connect the school work with home duties.

¹ This bulletin has been prepared in cooperation between the author and C. H. Lahe, Chief Specialist in Agricultural Education, as well as specialists of the Office of Home Economics, States Relations Service. It is designed to aid teachers in presenting a course of study in home economics which will connect such instruction and actual home experiences.

The principles involved in the lessons set forth in this publication are fundamental. However, it has been the purpose of the author to present those which have a direct bearing on southern home life. To secure the best results with this work teachers should make a special effort to adapt the lesson topics to the conditions found in the homes of the pupils. The first and most important step in this direction is for the teacher to make a close study of the community conditions, and so to direct the application of the principles given in the lessons as to meet the needs and to improve upon the conditions. Let the teachers keep in mind that communities as well as sections vary as to home-making problems and that a thorough knowledge of the conditions in each instance is necessary to enable the teachers to render the best service.

A complete course in home economics would include the following subjects:¹

1. Food:
 - (1) Selection (home-grown and purchased food).
 - (2) Preparation.
 - (3) Planning and serving of meals.
2. Shelter:
 - (1) House sanitation.
 - (2) Planning of house.
 - (3) Decoration and furnishing of the house.
 - (4) Care of the house
2. Clothing:
 - (1) Selection.
 - (2) Making.
 - (3) Keeping in repair.
 - (4) Laundry work.
4. Care and training of children:
 - (1) Care of a baby.
 - (2) Problems of a young child.
 - (3) Amusements for children.
5. Hygiene and sanitation:
 - (1) Definition of health.
 - (2) Definition and classification of diseases.
 - (3) Means of preserving health.
6. Home care of the sick.
7. Household management, including systemization of housework, expenses, accounts.
8. Training for the enjoyment of leisure time.

Many of the high schools of the South which teach agriculture and home economics are located in the open country and have dormitories for housing the students, which provide opportunities for practical instruction in home economics comparable to those furnished by the school farms for practical instruction in agriculture. Often much of the food material is raised by the boys on the school farm and much of the household work is done by the girls, thus

¹ See Syllabus of Home Economics, American Home Economics Association, Baltimore, Md.

reducing the expenses of each student to as low as \$5 to \$6 a month in some schools. In such cases the students may work one to two hours daily, or self-supporting students may do extra work beyond the stated requirement at so much per hour. This practical work serves both to introduce the problems in agriculture and home economics which are the basis of work in the classroom and furnishes the field for their practical application. The daily routine in housework, unless it is supervised, however, is of no educational value; it should be considered a part of the girls' laboratory work and organized accordingly.

Methods of teaching.—Early home economics, which was practical cooking taught by definite recipes copied and followed by the students, was soon modified both in the direction of "culture" by adding informational material from geography, history, and nature study, and in the direction of "science" by teaching applied chemistry and physics, i. e., the principles of these sciences with illustrations drawn from the household. The latter plan really teaches these sciences, however, and not home economics itself. It is now recognized that home economics consists of a definite body of principles, which are best taught as a self-constituted science, i. e., as an organized body of specific facts and principles, rather than as an application of other sciences. The relation of the material to the needs of the girls is in this way more definite and the approach of the subject through the girls' own home experiences is more direct, and the facts learned are better correlated with the needs of everyday life. Using as the basis of the course, therefore, the principles of home economics themselves, the teacher can by proper choice of problems teach the child those facts which are likely to be useful to her, presenting them in the order of their increasing difficulty.

The next matter, that of determining the method by which these problems are to be solved, or the presentation of the individual lesson, is the point at which teachers of home economics are most likely to fail.

How not to teach is well illustrated by a lesson actually observed. The problem was the freezing of water ice. How was it developed? As a first step which removed the necessity for any reasoning on the part of the students, the complete directions were dictated, and each girl took them down verbatim. No opportunity was given to the students in working out this problem to formulate any principles which could be applied to the making of water ices in general. Next the work was parceled out and each girl was given one step in the process, no one having a chance to follow the whole process through. The amount of lemon juice and sugar was arbitrarily stated. The students were not told that the amount of sugar should vary with the acidity of the fruit they used, nor were they allowed to find

this out for themselves. They had no opportunity to see that the mixture tasted sweeter before freezing than it did afterwards, and there was no discussion of this fact. No reason was given for the use of salt with the ice in the freezing mixture nor was the proportion discussed, but arbitrarily given. There was interest in the lesson, but it centered in the eating of the product after it was finished rather than in the principles involved in the making. From this example it may be seen that there is danger of much poor teaching in a subject which has the possibility of as good teaching as any other in the curriculum. While the example cited is of especially bad teaching, it is true in most cases that teachers of home economics tell the students too much, and do not allow them to reason things out sufficiently for themselves. Advocates of the method of teaching by means of problems agree that the subject-matter must be developed gradually in class. The teacher must not tell; the pupil must be required to make plans before she begins to work, and so be made to think things out for herself, keeping at the same time a live interest in technique.

When this method is used in teaching home economics it means that the problems given must be kept quite simple at first and the facts and principles which should grow into the life of the girls be developed gradually, step by step. It means thorough organization of material and thorough understanding on the part of the teacher of the principles involved. It means that students be given a very clear idea of the problems to be solved and trained toward definite standards of work. The danger in such a method lies in the fact that in the interest of learning the reasons for the different steps the standards for results may be lowered and drill on special points missed. This can be obviated by repeating those problems whose results are unsatisfactory and by having drills at stated intervals.

The best method of opening up a lesson is by questions which call to mind past experiences of the students and relate them to the problem (the preparation step in the formal lesson outline). Next there should be a very definite statement of the problem, made clear by additional questions (the presentation step). A list of these questions carefully worked out with a short and definite statement of the problems, should be given at one laboratory period to enable the student to prepare for the next. If the students study this carefully they are ready to start work at the beginning of the next period. An opportunity for questions should be given before starting work, but too much discussion at this point results in "telling." After the work is done the most valuable part of the lesson comes, the comparison of results and discussion of differences, leading to generalizations which form the theory of the subject in

hand. Thus theory grows out of practice, and to make the cycle of knowledge complete, it should be applied again in practice.

The following lesson plan illustrates this method of teaching. To formulate questions the teacher must have in mind a very definite logical outline which the questions will develop, but in actual questioning she should follow the order of the students' own way of thinking.¹

OUTLINE FOR A LESSON ON SPONGE CAKE.

(This lesson has been preceded by one on omelettes and soufflés, and will be followed by one on custards, or the use of eggs as a means of thickening.)

What do you understand by the term sponge cake? What types of sponge cake have we? What would you say were the characteristics of this group of cakes? What are the necessary constituents? How do they vary in the different types? In what kind of sponge cakes do you use cream of tartar? In which do you use lemon juice? Can you see any reason for this difference? Classify any recipes you may have for this type of cake on the basis of the amounts of the different constituents necessary for each egg.

Sponge cake.—You will find that for each egg in the sponge cake proper the general proportions of flour and sugar are the same, about one-fourth cup of each and one teaspoonful of lemon juice to each egg. Is any other liquid necessary? Upon what will this depend? What is the danger if too much is added? What will be the result if the amount is too little? In what order would you mix the above ingredients? What must be your aim all the time? The egg serves what functions in this cake? If eggs were expensive what two ingredients might you use in their place? To what extent can this substitution be made? Calculate the amount of each you would add as a substitute for one egg.

Let each student make a typical sponge cake, or a cheap sponge cake with one egg. Calculate the cost of each and compare the results. Are we justified in paying extra amount for the typical sponge cake? Is the cheap sponge cake wholly representative of this group?

Angel cake.—In what sense is an egg white equivalent to half an egg? On this basis work out your proportions for the angel cake from those used for the sponge cake. Could you make a cheap angel cake? What would be the limit to the amount of substitution possible here? Why do we add cream of tartar to the angel cake and lemon juice to the sponge cake?

Each student should make an angel cake, using the whites of two eggs. Make this either into a typical or a cheap angel cake. The

¹ The students are expected to answer the questions from their own experience so far as possible. Where their experience along any of these lines has been limited, it may be supplemented by reference to books in the library. Recipe books are especially valuable in giving suggestions as to proportions, combinations, etc.

yolks should be very carefully put away in the jars provided for that purpose as they are to be used at the next laboratory period.

Sunshine cake.—How does the sunshine cake differ from the sponge cake on the one hand and the angel cake on the other? Formulate the proportions for a small sunshine cake. Which would you use in this case, cream of tartar or lemon juice?

Any of the students who wish may substitute sunshine cake for either the sponge or the angel cake.

Baking the cake.—At what temperature did we find that eggs should be cooked? Since the typical sponge cake contains a very large proportion of egg, in what way would this determine the oven temperature? What is going to make your cake light? If the oven is too hot, what will happen to the top of your cake before it is fully raised? What will be the result in the cake? What temperature do you think would be most desirable for baking the above mixture? Would you use different temperatures for the typical and the cheap sponge cake? Reason.

The objections raised to the above method of teaching are three:

1. It is said to be slow and wasteful of material. Experience shows, however, quickness in real progress. While so much ground may not be covered, general principles are acquired, applicable anywhere. The knowledge has become a part of the student; it sticks better. In most cases there is no more waste than in the imitative recipe method. Material is not expensive, and with proper oversight failures are uncommon.

2. It is said that recipes should be standardized by experts and given to others in definite forms. But recipes must be indefinite since (a) food materials vary, not being chemically definite substances, and (b) the recipe itself varies with the result sought. It is far better to give the girl ability to utilize successfully whatever materials she may have available than to teach her to follow a small number of recipes.

3. It is said that teaching by recipes is the best means we have of cultivating correct food standards in the students, but it is doubtful whether it is wise to insist absolutely on uniform standards for all. Recipes can not be used as exact guides as long as the composition of ingredients is variable, and people differ in their tastes.

Correlation.—A good scheme for correlation used by a San Francisco school is as follows: Each teacher outlines her work in advance in general terms for each quarter, and more in detail for each month and week. These outlines are discussed in faculty meetings, each teacher stating the point at which she would like help from the others. As a result of these discussions other points of correlation are seen.

The practical outcome of these discussions is seen by an examination of the chart used by these teachers. There are as many columns

in each direction as there are courses for the given year. In each square there is a hook upon which a library card can be hung. In the top square of her column the teacher places on a yellow card her monthly outline, and each week a pink card containing a more detailed outline of that week's work. When a teacher wishes correlative work from another department she writes her request on a white card which she hangs in her column, and in the square corresponding to the department from which the work is desired.

	Home economics.	History.	English.	Mathe- matics.	Science.
	(Place monthly and weekly outlines here.)				
Home economics.			English makes request of home economics.		
History.	Home economics makes request of history.				
English.					
Mathematics.					
Science.					

The above chart is supposed to be divided into squares.

In this way we may find across the top of such a board an outline of the work in each subject, while the up-and-down columns show at a glance what the various departments are expecting of each other during the current week. When the work is planned sufficiently in advance there is no difficulty in preventing conflicts.

LABORATORY EQUIPMENT.

Food work.—Individual equipment of table, stove, and utensils is desirable. However, when expenses must be kept down, a minimum equipment may be secured for \$50, consisting of 12 individual sets of utensils, each costing about \$2, and general equipment costing \$25, including one three-burner oil stove and a supply table; for cooking tables whatever is available must be utilized.

Special cooking tables allowing working space of about 3 by 2½ feet can be built in or purchased ready-made. They should provide storage room for utensils and food supplies underneath. Individual gas plates or stoves are desirable. If there is no gas, individual oil stoves are preferable, since gas-manufacturing plants, like acetylene, are not common in the home.

Cupboards, a fireless cooker, a refrigerator, and a wheeled supply table with shelves below for food materials are desirable. If possible, a dining room, or at least space for a dining table, should be arranged to afford practice in table service. The cost of china, silver, glass, and linen may be estimated at \$62. Schools planning cooking equipment should send for catalogue to any large wholesale hardware company.

Sewing.—A sewing room should have tables 3 feet wide, allowing $2\frac{1}{2}$ feet in length for each student. The general equipment should include sewing machines, dress forms, mirror, fitting stand, skirt marker, cabinets; and the individual equipment, scissors, yardstick, foot rule, tape measure, pincushion, emery, pins, and needles. Equipment cost about \$1 per pupil in addition to general equipment.

OUTLINE OF LESSONS.

The following order has been used for each lesson: (1) The subject, stated as a "Problem." (2) The chief ideas, listed as "Points to be brought out." (3) The references, which have been confined to material available in bulletins of this department and of the various State colleges and experiment stations. Two textbooks should be obtained, one on foods and one on clothing. The choice of these must be left to the teacher. She should select them only after a careful examination of those available. The one on foods should be something more than a book of recipes; it should consider the principles of cookery, composition of food, and the principles of dietetics. The book on clothing should contain material on the selection of clothing, clothing standards, application of design to dress, the hygiene of dress, and a study of fabrics as well as drafting and the principles of sewing. If any part must be omitted let it be the latter, for the teacher can easily provide herself with a textbook on drafting and sewing so as to give the students the necessary information.

There should be in the library some additional books dealing with the composition, nutritive value, and digestibility of food. A good recipe book will be useful not for arbitrary use but for suggestions and comparison. It should not be misused. A good book on home laundry work, one on house sanitation, one on the care of the house, one on personal hygiene should be available for reference work. Copies of a good household chemistry, household bacteriology, and household physics will be found useful.

There are a number of such books¹ available at the present time. For a teacher of home economics to keep up to date in her work she must see the new books as they are published. Most publishers will send copies for examination which can be returned without cost to the teacher if they prove unsuitable for her purpose.

Bulletins are issued frequently which will be of help. These can in many cases be obtained free. The teacher's name should be on the mailing list of the Department of Agriculture for the Monthly List of Department Publications. She may send for any which interest her.

(4) Under "Correlation" are suggested ways in which other courses may make use of home-economics subject matter, thus in-

¹ See U. S. Bur. Ed. Bul. 613 (1914).

creasing the value of the latter and doing much to keep the former vital. Under "Supplementary Topics" are mentioned topics of household concern not directly related to the home-economics lesson of the day, but which may well be included in English work.

Each year's course consists of 160 lessons covering the subjects of cooking and sewing, with related hygiene and sanitation, and with review lessons at proper intervals.

LESSONS FOR FIRST YEAR'S COURSE.

LESSON 1.

Problem.—To plan, select the material, and estimate the amount of material necessary for (1) a dish towel, (2) a holder, and (3) a kitchen apron.

Points to be brought out.—Towels should be of as inexpensive material as possible, should absorb water readily, and should leave no lint. Holders should be constructed of material which does not burn readily and which is a poor conductor of heat. Aprons should be white, easily laundered, of simple design, and easily made.

References.—Write to State leader of girls' clubs for design of apron used in canning clubs.

Correlation.—Physics: Study conduction of heat (in connection with the selection of the material for the holder).

LESSON 2.

Problem.—To make the towel, holder, and apron.

Points to be brought out.—Making a neat machine hem on both straight and curved edges. Sewing on tapes. Overhanding or binding of the different layers of the holder together.

References.—Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2.

Correlation.—Arithmetic or English: Estimate the cost. • Physics: Capillarity of woven fabrics.

LESSON 3.

Problem.—To can any fruit in season. To examine the stove and learn to understand all drafts and openings.

Points to be brought out.—In canning we wish to preserve the fruit in as nearly the natural condition as possible or in the condition in which we would serve it. Cooking in the can or jar is the easiest and the simplest method. Sugar is not used as a preservative in this case, but should be used in amounts just sufficient for good flavor. The essential points in the management of the stoves should be brought out during this lesson.

References.—U. S. Dept. Agr., Farmers' Buls. 426,* 521, and 771.

Correlation.—Physics: Study of conduction, convection, and radiation of heat, as applied in the stove. The insulated oven. The fireless cooker.

NOTE.—If possible plan an additional lesson on the canning of fruit in which one of the outdoor canners is used in the orchard. In this case can in tin. Show how the culls, which would in many cases be wasted, may be utilized. This work could be given with all the girls in places where large amounts of fruit are available. There might be a contest between the different classes. Aim to emphasize the economic side and at the same time give the girls opportunity to work with large quantities of material. This lesson may be substituted for one of the following lessons or given as an extra lesson on the weekly holiday.

LESSON 4.

Problem.—To study the relation of microorganisms to the spoiling of food.

Points to be brought out.—Since microorganisms which may cause the spoiling of food are present all about us extreme care is necessary to prevent the contamination of food. In preserving we must kill all the microorganisms present or prevent their development. Simple heating at the boiling point for 15 to 20 minutes is sufficient in the case of fruit. Most vegetables are more difficult to sterilize. They must be heated for several hours. A shorter time may be used at a much higher temperature such as is obtained under pressure, or the material may be heated for a shorter time on three successive days.

References.—Preservation of Food in the Home, Univ. Mo. Bul., 15 (1914), No. 7, pp. 1-8; U. S. Dept. Agr., Farmers' Buls. 359, 426,* and 521.

Correlation.—English: Stories of germ life.

LESSON 5.

Problem.—To can any available vegetables, using the following methods: (1) Cooking on each of three successive days, (2) long cooking at the boiling temperature, and (3) cooking under pressure, if possible. Compare the methods as to time and trouble involved, the keeping qualities of the products, and the amount of fuel required.

Points to be brought out.—Complete sterilization is more difficult in the case of vegetables than in the case of fruits. The comparative value of the different methods of canning. The canned vegetables are an important addition to the winter's dietary.

References.—U. S. Dept. Agr., Farmers' Buls. 259*,¹ pp. 30-32; 359.

Correlation.—Arithmetic: Estimate cost of home-canned vegetables, taking into consideration the different factors involved. Compare with the cost of the factory-canned material. English: History of canning industry (Encyclopedia).

¹ Farmers' Bulletins marked with an asterisk throughout this publication are not available for free distribution, but may be secured from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 5 cents a copy.

LESSON 6.

Problem.—Canning vegetables, continued. Use any vegetables available.

Correlation.—English: Select from lists of U. S. Department of Agriculture a Farmers' Bulletin on some aspect of vegetable foods or cookery which would be useful in your home, and write to the Secretary of Agriculture, Washington, D. C., for it.

LESSON 7.

Problem.—To launder kitchen towels and aprons.

Points to be brought out.—The soil and dirt may be removed by solution, emulsion, and mechanical means; soaking helps to loosen them. Clothes should be thoroughly rinsed in order to remove the last traces of any material in solution, as well as the soluble cleansing agent.

References.—Rose, The Laundry, Cornell Univ. Reading Courses, 1 (1912), No. 11, pp. 133–136; Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2.

Correlation.—Chemistry: Soaps. English: Soap-making (Encyclopedia).

LESSON 8.

Problem.—To prepare fruit juices, some to be used the next day for making jelly, and the remainder to be sterilized and kept for winter.

Points to be brought out.—When the juice is to be used in making jelly the fruit must be cooked in order to extract the pectin, which is an essential constituent of jelly. The juice to be used in jelly making may be allowed to drip or may be extracted by pressure; the former method makes a clearer jelly, but often at the expense of flavor and quantity. The juices to be used for purposes other than jelly making preserve more of the natural flavor if extracted cold and sterilized at the lowest possible temperature.

References.—Univ. Ill. Bul. 8 (1911), No. 7, Goldthwaite; Preservation of Food in the Home, Univ. Mo. Bul., 15 (1914), No. 7, pp. 21, 22; U. S. Dept. Agr. Farmers' Buls. 78*, p. 29; 122*, p. 27; 175*; 644.

Correlation.—Arithmetic: Comparative cost of clear and cloudy jelly.

LESSON 9.

Problem.—To make jelly from some of the juice prepared in Lesson 8.

Points to be brought out.—Three constituents are necessary for successful jelly making—acid, pectin, and sugar. The amount of sugar added depends not so much upon the amount of juice as upon the amount of pectin in that juice. The usual proportion of sugar, one cup to each cup of juice, is too much in the case of a juice in

which the amount of pectin is small or in the case of a fruit in which large amounts of water are necessary for the extraction. It should be cooked until it jells. This point has been reached when a thermometer inserted in the solution indicates a boiling point of 103°C . (217°F). In a few cases it is necessary to cook the juice to a higher temperature, 105°C . (218°F).

References.—Univ. Ill. Bul., 8 (1911), No. 7, Goldthwaite; Preservation of Food in the Home, Univ. Mo. Bul., 15 (1914), No. 7, pp. 23–29.

Correlation.—Physics: The effect of substances in solution upon the boiling point of that solution. Arithmetic: Explain the different thermometers, Fahrenheit and Centigrade, and compute changes of readings from one to the other.

LESSON 10.

Problem.—Examination of the jellies made last time, an analysis of the process, and a discussion of the reasons for any variations in the results.

Points to be brought out.—Failure may be due to (1) absence of pectin in the juice. This can be determined by the alcohol test. (Ref. Univ. Mo. Bul., 15 (1914), No. 7, Preservation of Food in the Home, p. 23); (2) a deficiency of acid which prevents a perfect jelly from forming. Sugar sometimes crystallizes out from a jelly made from juice containing a small proportion of acid. If cooked too long, a candy rather than a jelly will result.

References.—U. S. Dept. Agr., Farmers' Buls. 78*, 122*, 175*.

Correlation.—Chemistry: Result obtained by boiling cane sugar in an acid solution, and the effect of this in retarding crystallization.

LESSON 11.

Problem.—To study the water supply from the standpoint of its use for laundry purposes. Wash the laboratory aprons and towels in water from different sources and compare the ease of the process, the amount of soap required, and the appearance of the article after laundering. In case the water is very hard, test the effectiveness of various alkalis in softening it. Show how to detect an alkali.

Points to be brought out.—Hardness of water is due to the mineral matter in solution. Some of this is thrown out of solution when the water is boiled. Hardness of water which may be corrected by boiling is termed temporary hardness. That which is not remedied by boiling is called permanent hardness. Soap does not dissolve readily in hard water because it forms an insoluble compound with the mineral matter present. The scum which forms on the top of hard water when we use soap with it is an example of such an insoluble

compound. Alkalis soften water by throwing the mineral compounds out of solution. Care must be taken to avoid using an alkali which will harm the material to be washed.

References.—Rose, *The Laundry*, Cornell Reading Courses, 1 (1912), No. 11, pp. 114–117; Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2, p. 82; any good book on home laundry work.

Correlation.—Chemistry: Alkalis and the means of detecting them.

Supplementary topic.—Describe the water supplies on your homestead, and suggest ways of making the water supply more convenient at the house.

LESSON 12.

Problem.—To recook any jelly which was found unsatisfactory at the last lesson.

Points to be brought out.—If an examination of the juice shows too little pectin, add some from another source, such as apple or white rind of the orange or lemon. If the juice is not sufficiently acid, add an acid from another source, lemon juice or citric acid. In case the proper amount of sugar has not been used, make the necessary correction. In some cases a soft jelly may be stiffened by allowing it to stand for a short time in the sun.

References.—Univ. Ill. Bul., 8 (1911), No. 7, Goldthwaite; Preservation of Food in the Home, Univ. Mo. Bul., 15 (1914), No. 7, Covering with paraffin; U. S. Dept. Agr., Farmers' Buls. 78*, p. 29; 122*, p. 27; 175*.

Correlation.—Arithmetic: Estimation of the cost of the jelly. Comparison in cost with the commercial product.

Supplementary topic.—List the kinds of fruits you know which will and which will not jelly. Ascertain the localities in the United States in which fruit raising is an important industry.

LESSON 13.

Problem.—Let each student clean her room and write an account of the process, giving the reason for each step. Discuss these accounts in class and make a plan to be followed by each of the girls in the care of her room.

Points to be brought out.—Thorough airing of bed and room is necessary. In cleaning care should be taken not to distribute dust. In dusting it is best to work downward from the upper part of the room.

References.—Watson, *Rules for Cleaning*, Cornell Reading Courses, 1 (1912), No. 23; a good book on the care of the house.

Correlation.—Arithmetic or English: Time and energy cost of cleaning rooms. Cost of equipment and supplies used.

LESSON 14.

Problem.—To make marmalade.

Points to be brought out.—In a marmalade, although the fruit is much more finely divided than in the case of preserves, the fruit and juice should remain distinct.

Reference.—U. S. Dept. Agr., Farmers' Bul. 203.

Correlation.—Arithmetic: Compare the cost of marmalade and jelly.

Supplementary topic.—Discuss a plan for improving the quality of homemade preserves, etc., in a community by means of local institute or school of domestic science for farm women.

LESSON 15.

Problem.—To plan a cap and an apron to be worn during the daily cleaning of the rooms.

Points to be brought out.—The purpose of the cap is to protect the hair from dust. It can do this and at the same time be attractive. The design should be such as will admit of easy laundering. Let the students bring in designs to be discussed and from them make the selections. (The choice of the design will depend somewhat upon the experience of the class in sewing. In general, the simpler the better.) The apron should cover the dress completely. The bungalow apron now so much used is of good design, is easily made, and will serve to introduce the later work on a gown. (See Lesson 78.) It is not necessary to buy a pattern for this apron, since the design is very simple. The apron should be made of gingham in attractive colors, with the cap to match. Emphasize especially the desirability of a neat and attractive appearance while at daily work and the suitability of specially planned work clothing, rather than soiled, cast-off finery.

References.—Any current pattern book.

Correlation.—Arithmetic: Estimate the cost of cap and apron. Compare them with the cost of ready-made caps and aprons as priced in stores and mail-order catalogues.

Supplementary topic.—Outline a plan for the purchase by a group of 10 neighbors of a vacuum cleaner and gasoline engine to run it, each person to have it for a day twice a month; estimate costs, suggest rules for use, repair, transportation, etc.

LESSON 16.

Problem.—To wash with different kinds of soap in order to compare their cleansing action, their effect on the color and appearance of the garment, and their lasting quality. To test soaps for free alkali.

Points to be brought out.—Soap cleans by its emulsifying and dissolving action. Study the different soaps and washing powders available and classify them according to their uses.

References.—Rose, *The Laundry*, Cornell Reading Courses, 1 (1912), No. 11, p. 117; any household chemistry.

Correlation.—English: The relative economy of the use of different soaps and washing powders. Discuss ways of reducing the amount of mud tracked into farm houses, including changes outside and inside (as walks and doormats), personal habits necessary, etc.

LESSON 17.

Problem.—To make preserves, jams, and butters. The points of difference and the means of producing the different types.

Points to be brought out.—There is a definite standard for each of the above products. By controlling the conditions under which the different fruit products are made we determine which of the products shall result.

References.—U. S. Dept. Agr., Farmers' Bul. 203.

Correlation.—Agriculture or Nature Study: The fruits available in your community; best varieties. What new varieties might well be introduced into your community or on your homestead?

LESSON 18.

Problem.—Cut out and baste a dust cap and apron.

Points to be brought out.—The material should be carefully cut with long strokes of the scissors. The work is neater when the parts which are likely to slip have been carefully basted. We should not, however, baste unnecessarily.

References.—Directions sent out by leaders of canning clubs. Any good book on sewing.

Correlation.—English: Write a description of cap and apron and tell how they are made.

LESSON 19.

Problem.—To discover the effect of soaking cucumbers in brine. Weigh the cucumbers, place them in the brine, weigh them every day for several days, and note their loss of weight and the change in their appearance. Put into brine the material for the pickles to be made in the later lessons.

Points to be brought out.—Salt, and sometimes sugar, may be used to draw the surplus water from fruits and vegetables which we wish to preserve by the use of sugar, spice, and vinegar. When the material is finely divided, the water may be extracted by mechanical pressure. This is a good time to show the effect of the very common practice of soaking the fresh sliced cucumbers in salt water before serving. The salt draws the water from the cucumbers, toughening them and rendering them less rather than more digestible.

References.—U. S. Dept. Agr., Farmers' Bul. 521; Office Expt. Stas. Bul. 245, pp. 87-90.

Correlations.—Botany: Osmosis in relation to vegetable cells. Agriculture: The varieties of cucumbers and their culture.

LESSON 20.

NOTE.—A series of lessons on mending has been planned, the object of which is not only to teach the girls how to mend but to give them definite standards for the care of their clothes and to develop in them the habit of keeping their clothes in order. It therefore seemed desirable to distribute the lessons over the school year rather than to have them all together. An attempt has been made in these lessons to include all the types of mending which the girls will find useful and to introduce them in the order in which they seem most likely to arise. The girls should, if possible, at each of these lessons bring in any clothing that needs attention. According to the discretion of the teacher instruction may be given to the girls individually, or the individual needs may be made the basis of a class discussion.

Problem.—To outline the essential points in the daily care of clothing, with demonstrations, as of brushing, folding, etc. To darn stockings.

Points to be brought out.—Putting clothing away carefully does much to preserve its appearance. Neatness is essential. Frequent brushing and pressing do much to prolong the life of clothes.

Reference.—Textbook on clothing.

Correlations.—English: Write a story proving that a stitch in time saves nine. Arithmetic: Estimate costs, including the factor of time, of mending your own clothing, and the clothing of a family of six.

LESSON 21.

Problem.—To make soap, using, if possible, alkali leached from wood ashes.

Points to be brought out.—Soap is made from a combination of lye with fat. When these are combined in the correct proportions, the reaction of the soap is neither acid nor alkaline.

References.—Rose, *The Laundry*, Cornell Reading Courses, 1 (1912), No. 11. Ask the mothers.

Correlation.—Arithmetic and English: Calculate the time necessary to make soap and the cost. Is the factory product cheaper? What is "chip soap"? Make a drawing of a pump or water pipe, with a flexible hose to fill the tubs; also of a stopcock at bottom of tub to empty it. Describe.

LESSON 22.

Problem.—To remove the vegetables from brine and start making the pickles.

Points to be brought out.—The liquid in which the pickle is preserved is intended both to prevent decay and to give flavor. Unless the vegetable material is finely divided it must be heated in order to have the liquid penetrate. Finely divided pickles may be preserved raw if the pickling solution has sufficient antiseptic power.

Reference.—Same as in Lesson 19.

Correlation.—Arithmetic: Calculate the cost of the pickle.

Supplementary topics.—List the seasonal work in a household—i. e., tasks in addition to daily and weekly routine; for which should men of household help or hired help be secured? How many hours a day is it wise to work, thinking of a well-balanced life?

LESSON 23.

Problem.—To clean and care for a sewing machine.

NOTE.—This lesson is introduced at this point, as the machines have not been needed to any considerable extent up to this time. The first few lessons have served to introduce some of the problems involved in its use. The teacher should demonstrate carefully the cleaning and oiling of the machine and the essential points in changing the tension, etc. Each girl should have charge of a machine for a stated time.

Reference.—Book of instructions with machine.

Correlation.—English: Write a set of rules for the routine care of a machine. Costs of various machines (get catalogues). Can a gasoline engine be arranged to run the sewing machine? Make a drawing to show how.

LESSON 24.

Problem.—To finish the pickles.

Points to be brought out.—It is necessary to have every bit of pickle completely covered by the preserving fluid.

References.—U. S. Dept. Agr., Farmers' Bul. 521; Office Expt. Stas. Bul. 245, pp. 87-90.

Correlation.—English: Compare cost of factory and homemade pickle. What light does this throw on value of woman's home work?

LESSON 25.

Problem.—To score all food products preserved so far. Study the preserve closet. Prepare for a demonstration and exhibit for the neighboring women, to be held on a Saturday.

Points to be brought out.—There are definite standards to which these different food products should conform. The preserve closet should be kept in order and should be so arranged that all its contents are accessible.

Reference.—Univ. Mo. Bul., 15 (1914), No. 7, The Preservation of Food in the Home.

Correlation.—English: Draw a plan and make out specifications for a preserve closet; give reasons for its distinctive features.

LESSON 26.

Problem.—To work on apron and cap.

Supplementary topic.—Explain the relation of a public library to the home life of its patrons. What does it do for them? Can loans of books be secured by your community from your State, county, or other library?

LESSON 27.

General review.

LESSON 28.

Problem.—To finish apron and cap.

Supplementary topics.—How might six neighbors organize a magazine club, each subscribing for one magazine and exchanging, so as each to get the use of all six? Draw up plan, list of magazines, costs, rules for ordering, for exchange, etc.

LESSON 29.

Problem.—To sterilize petri dishes and plate. Pour tubes of agar into petri dishes for experiments in the next lesson.

NOTE.—The tubes of agar should be prepared by the teacher or an advanced class.

Points to be brought out.—For any material to remain aseptically clean it must not be touched by anything which has not been sterilized.

Reference.—Any good bacteriology of the household.

LESSON 30.

Problem.—The weekly care of the bedroom. On the day usually devoted to this work the room should be carefully cleaned and an account written of the various steps, with the reasons for them. The following experiments with the petri dishes are suggested to make the reasons for the various steps in the cleaning process more clear: Expose 12 petri dishes as follows: (1) Immediately after sweeping a carpet, (2) immediately after sweeping a bare floor, (3) one-half hour after sweeping, (4) one hour after sweeping, (5) one and one-half hours after sweeping, (6) two hours after sweeping, (7) after dusting with a feather duster, (8) after dusting with a dry cloth, (9) after dusting with an oiled cloth, (10) after making a feather bed, (11) after brushing a skirt in the room, and (12) after brushing shoes in the room.

NOTE.—The purpose of these lessons is to give directions for the care of the room. Stress just those points which seem to be most needed by the different girls. These experiments can be outlined on any convenient day and the plates exposed whenever the rooms are cleaned.

Points to be brought out.—A bare floor is more sanitary than a carpeted one. In sweeping we should aim to collect and remove dust, not to scatter it. A sufficient time should be allowed after sweeping to insure the settling of the dust. An oiled cloth is best for collecting dust. Making a bed, brushing a skirt, and brushing shoes all serve to distribute dust and bacteria in the room.

Reference.—Watson, Rules for Cleaning, Cornell Reading Courses, 1 (1912), No. 23.

Correlation.—English: Write an account of the ways that girls pollute the air of their rooms unnecessarily. Make constructive recommendations.

LESSON 31.

Problem.—To prepare oil dusters and equip a cleaning closet. There should, if possible, be a cleaning closet accessible to the girls on each floor of the dormitory or of the home. If this is already equipped, the equipment should be carefully gone over and put in order. The girls should be responsible for seeing that it is kept in order. This furnishes a splendid opportunity for the study of equipment for cleaning.

Points to be brought out.—Time is saved in cleaning and the work is better done if good apparatus is provided. A cleaning closet is desirable for then we know where to find our cleaning appliances.

Reference.—Watson, Rules for Cleaning, Cornell Reading Courses, 1 (1912), No. 23.

Correlation.—English: Write a description of and estimate the cost of equipping a cleaning closet. List costs of improved cleaning appliances—dustless dusters, carpet sweepers, and hand vacuum cleaners. Would the gasoline engine used on milk separator and washing machine run a vacuum cleaner? How? (Get catalogues and prices.)

LESSON 32.

Problem.—To make vinegar.

Points to be brought out.—Microorganisms are not always harmful in the household. By controlling them properly we may make them useful. We may use them in the making of vinegar.

References.—U. S. Dept. Agr., Farmers' Buls. 233*, p. 28; 276*, p. 28.

Supplementary topic.—English: Beekeeping, a vocation for farm women. (Secure Farmers' Bulletins, catalogues.)

LESSON 33.

Problem.—A summary of the uses to which we may put microorganisms in the home.

Points to be brought out.—The importance of microorganisms in the ripening of cream and cheese, and in bread making.

Excursion.—Visit the school dairy or a near-by creamery and see how the milk is ripened with a starter, and, if possible, watch the process of cheese making.

Correlation.—English: Write an account of the excursion.

Supplementary topic.—Methods of organizing cooperative creameries. What household work might be handled cooperatively? Could washing? (See Journal of Home Economics.)

LESSON 34.

Problem.—Make short-process bread, using compressed yeast if available. If there is a bakery in the vicinity the yeast can usually be procured there, which grows very rapidly when the yeast is fresh.

Points to be brought out.—The time required in making the bread, other conditions being the same, is directly dependent upon the amount of yeast used.

Reference.—U. S. Dept. Agr., Farmers' Bul. 807. Textbook on foods.

Supplementary topic.—Essay on the Baking Industry in your home community in its relation to your home. What does it do, what might it do, for your home?

LESSON 35.

Problem.—Examination of the petri dishes exposed in the lesson on cleaning (p. 18). So far as possible, distinguish between the bacteria and yeast on the one hand and the molds on the other.

Points to be brought out.—The plates exposed at different lengths of time after sweeping show that the microorganisms have not completely settled until about two hours after sweeping. There is danger of distributing disease germs when we brush shoes and skirts in the room.

Reference.—Any book describing bacteria, yeasts, and molds.

Supplementary topic.—English: Describe the arrangements which you would suggest, in an ideal household, for cleaning shoes and clothing.

LESSON 36.

Problem.—To wash the individual towels from the bathroom. List the processes involved.

Points to be brought out.—Boiling is valuable as a means of cleansing and as a means of disinfection. It is possible to transmit disease by means of garments, towels, etc. Fresh air and sunlight are valuable disinfectants. Bluing is used to neutralize the slight yellow color which comes as the natural result of the action of hot water and alkali on the textile fabrics. Only a slight amount is necessary for this. More is used to cover up careless work and gives a dirty, dingy, blue color to the clothing. Kinds of bluing: (1) Indigo—little used; (2) Prussian blue, an iron compound, frequently causes iron rust stains; (3) ultramarine blue, a mineral compound, used in suspension; and (4) aniline blue, a coal-tar product, the cheapest and most common type of bluing. Test and identify the bluing ordinarily used.

References.—Rose, The Laundry, Cornell Reading Courses, 1 (1912), No. 11. Any good book on home laundry work.

Correlation.—Chemistry: Methods of identifying the different bluing.

LESSON 37.

Problem.—To make short-process bread into coffee cake, cinnamon rolls, Swedish tea rolls, Sally Lunn, etc.

Points to be brought out.—Necessity for practice in handling the dough and managing it so as to promote the growth of the yeast.

Short-process bread is usually lacking in flavor and a little cinnamon and sugar will conceal the absence.

Reference.—Any good book on food preparation.

Correlation.—English: Write a description of how each of the above products should be made.

LESSON 38.

Problem.—Study of yeasts and conditions under which they live best. Study the forms in which they may be obtained. Start sponge from yeast foam.

Reference.—U. S. Dept. Agr., Farmers' Bul. 807.

Correlation.—English: Write a story of a cake of yeast.

LESSON 39.

Problem.—To make bread, using sponge from the dried yeast, the so-called yeast foam. Use bread mixer.

Points to be brought out.—In the dried yeast cake the yeast is in a dormant state. It must have time to get started, therefore we soften the cake with luke-warm water and let it grow in the sponge. Dried yeast is used almost exclusively in the country because it does not deteriorate rapidly. The bread should be formed into loaves which are not too large to permit of proper baking.

Reference.—Textbook on food.

NOTE.—Do not let the students get the idea that compressed yeast can not be used in making long-process bread.

Correlation.—English: Describe the different kinds of yeast available, with prices.

LESSON 40.

Problem.—To score bread and review all the steps involved in its making.

Points to be brought out.—If good bakery bread may be obtained it is sometimes uneconomical to make bread at home. The cost of fuel and the value of the worker's time must be taken into consideration.

Reference.—Any good book on food preparation.

Correlation.—Arithmetic: Compare the cost of homemade and baker's bread.

LESSON 41.

Problem.—To inspect kitchen linen and make additional towels, if any are necessary.

Points to be brought out.—There should be an adequate supply of dish towels and cloths. Both should be neatly hemmed. The best materials are those which absorb water easily and leave no lint.

Correlation.—Arithmetic: Determine the amount of kitchen linen necessary for a family of six and estimate the cost.

LESSON 42.

Problem.—To grow yeast.

Points to be brought out.—Yeasts are grown, not made.

References.—Any old-fashioned recipe book. Ask mothers for method they have used.

Supplementary topic.—Discuss possible ways of shortening the work-day of the farmer's wife. Is it longer than the man's day? Will shortening his help hers?

LESSON 43.

Problem.—To make bread from yeast grown in different ways and to compare the resulting flavors. Start sponge for the salt-rising bread. (See next lesson.)

Points to be brought out.—The yeasts grown in the different ways may affect the flavor of the bread through some constituent which in itself may change the flavor, or through the retarding action of some one constituent on some of the microorganisms which may enter the brew. The sponge must contain an abundance of carbohydrate material, part of which is in soluble form, and sufficient nutritive material for the growth of the yeast. Hops are added as an antiseptic.

Correlation.—English: The yeast industry, the wheat belt, the flour industry.

LESSON 44.

Problem.—To make salt-rising bread.

Points to be brought out.—Bacteria may be used as well as yeast in the production of gas to make bread light. Cornmeal is used in the household as a source of these organisms when we make salt-rising bread. We always find in conjunction with them certain other organisms which give the typical flavor to the bread. Salt is used in this bread to prevent the growth of some undesirable organisms. Milk is essential as food for the bacteria. They grow best at a higher temperature than yeast. This bread has a distinct flavor very much liked by some.

Suggestion.—This can be made into a loaf or served hot in the form of rolls. It is especially desirable for toast. Baking it in small baking powder tins gives the whole loaf a brown crust and insures round, well-shaped slices.

Supplementary topic.—Breads of different lands. Stoves of different lands.

LESSON 45.

Problem.—To finish the work with the kitchen linen. It should all be marked and put away in an orderly manner. The first-year students may have the task of keeping the kitchen linen in order for the year.

Points to be brought out.—Linen should be carefully marked and the date of its acquisition added so that we may know how long the dif-

ferent kinds wear. A linen closet should be planned so that the different kinds of linen can be kept separate and a person can tell at a glance just what is lacking.

LESSON 46.

Problem.—How to keep well.

Points to be brought out.—*Health* is that condition of the body and its organs necessary to the proper performance of their normal functions. *Disease* is a pathological or abnormal physiologic state.

Kinds of disease: (1) Autogenic, those which arise in the body—indigestion, rheumatism, gout, nervousness, etc.; (2) contagious, those which are due to micro-organisms coming from the outside. *Prophylaxis* is the use of hygienic or other precautions for the prevention of disease. It may consist of (a) disinfection, (b) keeping the body in healthful condition so that it may resist the attacks of disease-producing microorganisms. *Means of keeping well and strong:* (1) Eating proper food in proper amounts, (2) getting sufficient fresh air and exercise, and (3) maintaining cleanliness inside the body and outside. It is our duty to keep well. We become ill when we disobey the laws of nature.

Reference.—Any good book on personal hygiene.

Supplementary topic.—Estimate in dollars and cents the cost to the family of the illness of some person whom you know. How is sickness a cost to the community? What does your community do to protect its members against sickness?

LESSON 47.

Problem.—General summary and review of bread.

LESSON 48.

Problem.—The relation of food to health.

Points to be brought out.—Food is probably the most important factor in the question of health. We should have it in proper kind and amount. Meals should be properly distributed throughout the day. The dangers from eating between meals are due to lack of sufficient intervals of rest for the stomach and also to the fact that food taken in this way is likely to take away the appetite for the regular meals. Girls who indulge in candy and sundaes between meals are liable to be undernourished. We need to study the food question carefully not only because certain autogenic diseases are the direct result of improper food, but because improper food lowers the body resistance and makes us more susceptible to contagious diseases. One of the best means of preserving health is the right choice of food.

Reference.—Any good book on food and nutrition.

Correlation.—Chemistry: Compare the composition of the body with that of some typical foods.

Supplementary topic.—What books on food should a housewife have? Plan the entire library of an ideal farmer's family. What general subjects would be included in such a library?

LESSON 49.

Problem.—To bake apples and to cook cranberries.

Points to be brought out.—Apples cook more quickly with the skins on and the cores removed. Water is unnecessary in most cases. The skin keeps in the steam and the volatile flavors. Apples which have been pared and cooked without any water in the fireless cooker approximate baked apples in flavor. In cooking cranberries we add the sugar at the beginning of the operation if we wish the berries to hold their shape, at the end if we wish to make a sauce of them. Fruits are very valuable in the daily dietary, because they furnish mineral matters and mild acids, and should appear in some form other than rich preserves at least once daily.

Reference.—U. S. Dept. Agr., Farmers' Bul. 293.

Correlation.—Chemistry: Make a list of some of the chemical elements which are important constituents of fruits and list the fruits in which they are present in the largest amounts. English: List and discuss varieties of apples available in your community. What kinds would you like on your farm?

LESSON 50.

Problem.—To study the relation of fresh air and exercise to health.

Points to be brought out.—Stress the value of fresh air and exercise. Night air is not harmful. It has been proved that outdoor sleeping even in cold climates increases the resistance to disease and renders one less susceptible to colds.

Reference.—Book on personal hygiene.

Correlation.—Physical training: Make out a weekly schedule which will furnish exercise of the proper type in the required amount; mention outdoor fun which a neighborhood group or a family group can occasionally enjoy together.

LESSON 51.

Problem.—To study the relation of personal cleanliness to health; toilet soaps.

Points to be brought out.—Personal cleanliness is necessary for the best health. It includes daily bath to remove perspiration, oil, etc., from the skin; care of teeth; care of hair; sufficient changing of clothing; and keeping the digestive tract clean. Constipation is the root of many ills. The purpose of the daily bath is to keep clean, not to get clean. The bath furnishes exercises to the skin. If one can stand the

effect of a cold plunge, it decreases considerably the tendency to catch cold. Toilet soaps should never contain a large excess of alkali. They should be made of pure fat. Perfume is frequently used to hide poor materials in soap making. The amount of water present in the soap determines the hardness of the latter. Since the way in which soap "spends" depends upon this hardness, it is wise to let the cake stand exposed to air for a while before using it.

References.—Books on personal hygiene and household chemistry.

Correlation.—English: Outline ways in which running water can be put into a detached farmhouse; a shower bath improvised. Determine the difference in the time a soft cake of soap lasts compared with a hard cake of the same kind.

LESSON 52.

Problem.—To cook dried fruit.

Points to be brought out.—Slow cooking helps to soften dried fruit and makes it absorb more completely the water lost in drying. Soaking is valuable as a means of decreasing the length of time necessary for cooking.

References.—Langworthy: Raisins, Figs, and Other Dried Fruits, and Their Use, U. S. Dept. Agr. Yearbook Separate 610; Farmers' Bul. 771.

Correlation.—Arithmetic: Determine the percentage of water absorbed in cooking soaked and unsoaked dried fruit. Compare the composition of cooked dried fruit with fresh fruit.

Supplementary topic.—List the kinds of dry fruit available, with prices. (Stores and catalogues.)

LESSON 53.

Problem.—Food as building material.

Points to be brought out.—Food does two things in the body—it furnishes energy and it furnishes the material from which the body fluids and tissues are formed. About 6 per cent of the body is made up of mineral material, and unless this is supplied in the food we soon see the effects of such a deficiency. It is ordinarily conceded that sufficient mineral matter is present in the diet as usually selected. This is true only if we select our foods wisely and prepare them so as to retain as much as possible of this mineral material.

References.—U. S. Dept. Agr., Office Expt. Stas. Buls. 185 and 227.

Correlation.—Chemistry: List the elements present in the body. Divide them into two groups, acidic and basic.

LESSON 54.

Problem.—To prepare mashed potatoes. These should be cooked in different ways—baked, boiled with the skin on, boiled with the skin off, and boiled after being peeled and cut into cubes. Cream each,

adding the same proportion of seasoning in each case. Compare as to flavor. If time and the following vegetables are available, compare also the flavor of tomatoes baked in their skins with stewed tomatoes, and beets baked in a tightly covered casserole with beets boiled in the usual way. (Unless the beets are very tender, the addition of a very small amount of water may be necessary.)

Points to be brought out.—Many of the flavoring principles of vegetables are volatile and are soluble in hot water. In baking a large portion of the volatile flavor is held in by the skin. Only those vegetables which have a natural protective covering and contain sufficient water to hydrolyze the starch and cellulose present can be successfully baked without an artificial outside cover such as a casserole or a paper bag. A tight casserole is better than a bag, because the vegetable can be served in the dish in which it is prepared. When vegetables are boiled and the liquor is poured off some of the nutritive material and much of the mineral salts are lost.

References.—U. S. Dept. Agr., Farmers' Buls. 256 and 295; Office Expt. Stas. Buls. 43* and 45*.

Correlation.—Chemistry: Make lists of the vegetables in which given elements predominate.

Supplementary topic.—English: Describe the vegetables which you have eaten and the ways in which they were prepared. What vegetables would you like to add to your kitchen garden at home?

LESSON 55.

Problem.—Making a bed, its daily care, and a study of the essential bed clothing.

Points to be brought out.—The bed should be aired each day. The bedclothes next the sleeper should be frequently changed, since they are likely to be soiled from contact with the body. In no case should we use bed clothing next us which can not be frequently washed. Characteristics desirable in bed covers are warmth and lightness.

Reference.—Any good book on household management or care.

Correlation.—English: Make a list of the bed clothing desirable for a family of six and estimate the cost. Discuss metal bedsteads versus wood; different kinds of mattresses, bed springs. (Visit stores and consult catalogues.)

LESSON 56.

Problem.—To put clothing in order and pack it properly for the holiday trip home. Any suits or dresses to be taken should be carefully pressed.

Points to be brought out.—All garments should be examined to see that they are in perfect repair. Sew on any loose fastenings. In packing all garments should be carefully folded so as to make as few

wrinkles as possible. Rolls of tissue paper or soft garments are frequently put between the heavier folds to prevent deep creases. The secret of successful packing lies in careful folding and in packing tightly, also securing the clothing in some way so it will not slide about. Well-packed garments can be taken out unwrinkled and ready to wear. Spots on a skirt are usually caused by the accumulation of dust in grease. The grease may be removed by the action of a solvent or by absorption.

Correlation.—Chemistry: Test the solubility of fat.

LESSON 57.

Problem.—To prepare the strong-flavored vegetables—cabbage, turnips, and onions.

Points to be brought out.—Much of the objectionable flavor of some vegetables can be avoided by cooking in an open vessel. Have the same vegetables cooked with the cover of the vessel on and some with the cover off. Discard all the liquor from some, retain the liquor which is poured off from others, concentrate to reduce the bulk, and further volatilize the flavor and use with suitable seasoning to make a sauce for the vegetable. In all the lessons on vegetables have them well seasoned and attractively served. Emphasize the lack of fat in vegetables and the value of adding it as seasoning. In communities in which olive oil is used it gives a distinctive flavor which is very much liked. One of the charms of Italian and Grecian cooking comes from the use of olive oil. Well-made cottonseed oil is also good.

References.—U. S. Dept. Agr., Farmers' Bul. 256; Office Expt. Stas. Bul. 245.

Correlation.—English: Discuss canned versus fresh vegetables; the facilities and value of methods for the household storage of vegetables.

LESSON 58.

Problem.—To prepare vegetables suitable for the Thanksgiving dinner. In this lesson the aim is to give the girls some suggestions to carry home with them. As many different ways of preparing vegetables as possible should be tried. Each girl should try at least one while at home and report upon its success. We should try to honor the occasion by using vegetables in unusually attractive ways.

References.—U. S. Dept. Agr., Farmers' Bul. 256; Office Expt. Stas. Bul. 245; Bureau of Education, Manila, Bul. 35 (Supt. of Documents, Washington, D. C.). Any good recipe book, especially one compiled in the vicinity.

Correlation.—English: Essay: (1) The Holidays, Festivals, and Birthdays, etc., of an American family, with suggestions for observances. (2) What can the family do to develop in its members the religious spirit which is at the basis of Thanksgiving Day?

LESSON 59.

Problem.—To prepare some vegetable for the Thanksgiving dinner. This is to be done at home and a written report submitted at the next meeting of the class.

LESSON 60.

Problem.—To put away summer clothing. (To be done while at home and a written report handed to the teacher.)

Points to be brought out.—All should be cleaned and mended. All buttons should be in place. Cotton and linen garments should be put away without starch and rough dried; all others should be carefully pressed and folded, and as far as possible each garment should be ready to wear when taken out.

Reference.—Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2.

Correlation.—English: What magazine seems to you to have the best discussions of dress; why? What magazines would you suggest for a farmer's family composed of father, mother, boy of 16, girl of 12, boy of 10, assuming that they have \$15 a year for magazines? Give reasons for your choice.

LESSON 61.

Problem.—Christmas sewing. Six lessons are given over to the Christmas sewing. No special outlines will be worked out for these lessons. The aim of these lessons should be to foster the true Christmas spirit and at the same time to furnish practice in some of the fancy stitches.

Points to be brought out.—In the making of Christmas gifts everything should be either useful or beautiful, wherever possible both. Emphasize especially the utility of the gift and its adaptation to the person for whom it is intended. Keep the expense down as much as possible. Teach the pupils to use the materials at hand and those which are available at slight expense.

Reference.—Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2, pp. 21-29.

Supplementary topic.—Discuss principles underlying the exchange of gifts between members of a family.

LESSON 62.

Problem.—To analyze the successes and failures in preparation of vegetables at home and discuss the selection and care of vegetables.

Points to be brought out.—Fresh vegetables should be used as soon as possible after gathering since the flavor changes on standing. Crispness is a desirable characteristic. This crispness comes from the presence of water and is lost with evaporation.

References.—U. S. Dept. Agr., Farmers' Bul. 375, pp. 24-28, 31-34; Office Expt. Stas. Bul. 245, pp. 91-94.

LESSON 63.

General review.

LESSON 64.

Problem.—To make peanut brittle. It is better to make this by simply melting the sugar without the addition of water.

Points to be brought out.—Dry heat melts sugar, changing it first to a light brown sirup which hardens on cooling and is the basis of brittle candies. If the heating were carried further there would be a continued browning and the material called caramel would be formed. Water is given off during the process of melting.

Reference.—Any good book on food preparation or candy making.

Correlation.—Arithmetic: Calculate the cost of homemade peanut brittle and compare it with the price of that bought at the store.

LESSON 65.

Start Christmas sewing. (See Lesson 56.)

Supplementary topic.—Make a working plan for the control of money in the family. Should the father have sole control, or father and mother plan jointly for expenditures? At what age should children be told about family finances?

LESSON 66.

Christmas sewing. (See Lesson 56.)

Supplementary topic.—Many children are given a regular allowance of money for clothing, for savings, for gifts. Write a story of a girl's allowance and what she did with it. What are the advantages in having an allowance?

LESSON 67.

Problem.—To make fudge.

Points to be brought out.—In making fudge we dissolve the sugar and other materials in water and cook until a definite concentration is reached, then by beating we recrystallize the sugar, or, as we say, make it "cream." In these candies we wish the crystals to be very small, so small that they can not be felt separately on the tongue. We are able to do this partly on account of a change brought about in the sugar during the cooking process, and partly by controlling the conditions under which the crystallization has taken place. The cooking changes are hastened by the addition of a weak acid. If too much acid is added the change goes too far and the candy will not cream at all. Does chocolate contain any acid? Brown sugar and sirups contain in varying amounts the same material to which sugar is changed on cooking, so when they are used acid is unnecessary. We control the crystallization by beating only after completely cold, not stirring unnecessarily while cooking, and by keeping the crystals which form on the upper part of the vessel from falling into the cooking sirup.

Suggestion.—This would be a good time to give the test for sugar. Have the girls test the candy in the usual household way to determine whether or not it is done, then take the temperature of the boiling solution at this point. Record and compare very carefully the conclusions of the different members of the class.

Reference.—Same as Lesson 64.

Correlation.—Physics: The relation of the boiling point of a solution to its concentration.

LESSON 68.

Problem.—To classify candies and study the principles underlying their preparation.

LESSON 69.

Christmas sewing. (See Lesson 56.)

LESSON 70.

Problem.—To make fondant, applying the principles worked out in the making of fudge.

References.—Same as Lesson 64.

Correlation.—Arithmetic: Estimate cost of fondant.

LESSON 71.

Problem.—To prepare Christmas decorations.

Points to be brought out.—Significance and spirit of Christmas. It is not a time for show nor merely for the exchange of gifts, but a season of happiness and good will to all.

References.—Current magazines; Betts, *The Christmas Festival*, Cornell Reading Courses, 3 (1913), No. 53.

Correlation.—English: Write Christmas stories.

LESSON 72.

Christmas sewing. (See Lesson 56.)

LESSON 73.

Problem.—A consideration of the place and value of candy in the diet.

Points to be brought out.—Sugar yields energy but no protein. Since it satisfies the appetite very readily, its free use may result in one's not taking a sufficient amount of other more important foods. On this account it should not be eaten before the meal but afterwards. Sugar may cause teeth to decay partly because the person who eats excessive amounts of sugar is not getting the right amount of material—mineral matter—to build teeth. We can not keep well and strong when we allow sugar to take the place of the protein which builds muscle or of the vegetables which supply mineral matter.

References.—Same as Lesson 64; also U. S. Dept. Agr., *Farmers' Bul.* 535, pp. 26 and 30.

LESSON 74.

Problem.—To make fondant. Duplicate as far as possible candies seen in the stores. Caramels, taffy, and divinity should be prepared this lesson. If it seems desirable and there is time, an extra outside lesson might be given on candy. In this all the girls would be interested. The candy might be sold or, in keeping with the holiday spirit, might be given to the poor in the neighborhood, or the students might furnish their own materials and take home with them the candy so prepared.

References.—Food text. A good recipe book.

LESSON 75.

Christmas sewing. (See Lesson 56.)

LESSON 76.

Problem.—To outline a plan by which an account can be kept of the expenditure of time and money.

Points to be brought out.—We must keep accounts in order to be able to tell whether we are getting adequate returns from our expenditures. We should keep account of the expenditure of time as well as money.

Reference.—Book on household management.

Correlation.—English: Home accounts as related to farm accounts, U. S. Dept. Agr., Farmers' Buls. 511 and 572.

LESSON 77.

Problem.—To review the work on sugars, classify the sugars and sirups.

References.—U. S. Dept. Agr., Farmers' Buls. 535 and 653.

Correlation.—English: Write stories of sugar growing and manufacture, and beet sugar in the United States.

LESSON 78.

Problem.—To plan a nightgown.

Points to be brought out.—The gown should be loose, simple, easily made, and easily laundered. The trimming should be flat and durable. The material should be soft and durable, without finish.

Suggestion for working out.—The kimono nightgown fulfills all these conditions, especially when it is made from 40-inch material. It is easily laundered. It may be ironed flat or may be put through the mangle. If made of crepe, it needs no ironing.

Reference.—Any good book on textiles or clothing.

Correlation.—Arithmetic: Estimate the cost of the nightgown. Drawing: Draw designs.

LESSON 79.

General review.

LESSON 83.

Problem.—To finish the neck and sleeves of the gown.

Points to be brought out.—That neatness and simplicity are desirable. The little machine scallops which come in dainty design make a neat and inexpensive finish. Turn the raw edge of the gown one-eighth of an inch toward the wrong side. Hold the narrow scalloped braid that the scallop stands out beyond the edge and at the same time the solid portion of the braid covers the raw edge of the turn. Carefully baste in this position and stitch with two rows on the right side.

Reference.—Same as in Lesson 81.

Supplementary topics.—Discuss the storage of one's personal clothing; the proper distribution of articles in bureau drawers; wardrobes with coat and dress hangers, etc., for both men and women of family. Work out a plan for partitions in a bureau drawer to store separately various kinds of things.

LESSON 84.

Problem.—To prepare cream toast, using flour to thicken the milk.

Points to be brought out.—Dry heat dextrinizes starch, making it more digestible. One tablespoonful of starch is equivalent to two of flour in thickening power. Before adding starch to a hot liquid it is necessary to separate the starch grains by suspending them in a cold liquid.

References.—Textbook on foods; any good recipe book.

Correlation.—English: List the dishes made with toast; tell how to make some one dish which you would like to try at home.

LESSON 85.

Problem.—To launder underwear which requires starch. It should be left to the next lesson for ironing.

Points to be brought out.—The reasons for starching are (1) a glazed surface keeps clean longer; (2) starch gives the material "body," increases its resistance to moisture, and makes it more attractive in appearance. The kinds of starch used are wheat, rice, and cornstarch. Materials stiffened with wheat or rice starch are more flexible than those stiffened with cornstarch.

Reference.—Any good book on home laundry work.

Supplementary topic.—Draw a plan for a home laundry and list the appliances necessary, with prices. (Consult catalogues and visit stores.)

LESSON 86.

Problem.—To iron the underwear washed during the last lesson.

Points to be brought out.—Materials which do not require ironing save much time. Extra time is required to iron elaborately trimmed underwear. Simplicity in trimming and design is desirable.

References.—Rose, *The Laundry*, Cornell Reading Courses, 1(1912) No. 11, pp. 142-146.

Correlation.—English: Estimate the amount of time required to iron properly narrow ruffles used as trimming. What type of trimming is most easily ironed and at the same time the most durable? Describe different irons available for your home. Compare the cost and the convenience of irons heated on the stove, by charcoal, wood alcohol, etc.

LESSON 87.

Problem.—To make cream soups, using the vegetables which contain very little starch, such as celery, cabbage, collard, cauliflower, or any other green vegetables.

Points to be brought out.—Cream soups are made in the same way as a cream sauce except that the liquid instead of being entirely milk, is composed of part milk and part the liquor in which the vegetable has been cooked, with as much of the vegetable itself as can be softened and rubbed through the strainer. The proportion of flour necessary to make a soup of the consistency of thick cream is one tablespoonful to each cup of liquid. As the amount of solid material in the vegetable liquor is increased, the proportion of flour added may be decreased. It is always necessary to add some flour, however, in order to prevent the heavy particles of vegetable from settling. The proportion of butter added is usually the same as that of flour. It depends in part, however, upon the flavor desired and the part the soup is to play in the meal. (Leave cream tomato soup until the milk lesson.)

References.—U. S. Dept. Agr., Office Expt. Stas. Bul. 245, p. 75; text-book on foods.

LESSON 88.

Problem.—To study the relation of clothing to health.

Points to be brought out.—The primary purpose of clothing is protection, not ornamentation. Clothing should not be so tight as to interfere in any way with freedom of movement. Shoes are made to protect the feet and to facilitate walking, not to make it more difficult. The clothing should be such as to admit of the proper ventilation of the body.

Reference.—Textbook on clothing.

Correlation.—English: Write a composition comparing American and Chinese styles.

LESSON 89.

Problem.—To make a bowl of palatable potato soup, and a variety of other cream soups from any available vegetables.

Points to be brought out.—The value of cream soups as a means of utilizing skim milk on the farm. A cream soup may be made nutritious enough for the principal dish at a meal. It should be made very thin if it is to serve as the first course at a full dinner. In the latter case whipped cream should not be added to the soup.

Correlation.—English: List all the different cream soups you have ever eaten or heard of, and tell how to make one which you would like to try at home.

LESSON 90.

Problem.—To plan a suit of underwear.

Point to be brought out.—The garments should be adapted to the purpose for which they are intended. There is much chance for improvement along this line.

References.—Clothing text. Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2. The intelligent study of any current pattern magazine.

LESSON 91.

Problem.—To draft the drawers. The design should have been selected in the previous lesson.

References.—Same as in Lesson 90.

Suggestion.—A draft for circular drawers may very easily be adapted from one for a circular belt or peplum. The latter may be drafted as follows:

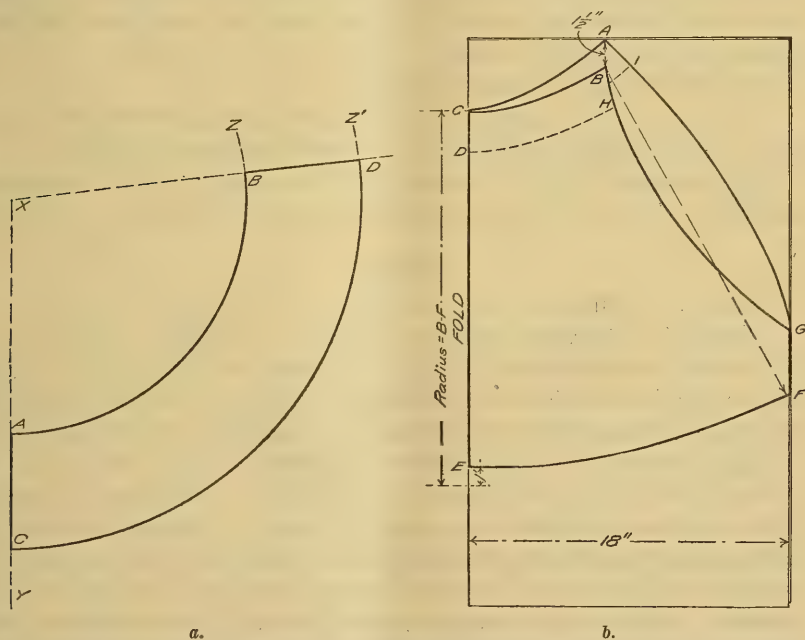


FIG. 2.—Directions for drafting circular belt: The measurements required are the waist measure and the depth of the belt. Draw a line of indefinite length (fig. 2a, XY). On this line mark point A at a distance from X equal to one-third the waist measure. Using X as a center and XA as a radius, draw an indefinite arc, AZ. On this arc mark point B distant from A by one-half the waist measure. From A on line XY measure the depth of the belt and mark the point C. Using X as a center and with XC as a radius draw an indefinite arc, CZ'. Draw a line from X to this arc through B and mark the point of intersection D. ACDB equals one-half the belt. In cutting lay line AC on lengthwise fold of the paper or goods. Directions for drafting circular drawers: Fold the pattern for circular belt as shown in figure 2b (AI-CD-BH). The line CD is folded in such a way that B is $1\frac{1}{2}$ inches below A. Lay on paper 36 inches wide, folded down the center. The fold CD should be placed upon a fold of the paper. From C measure the length desired for the side of drawers, that is, down over the hip (CE). With B as a center and a radius equal to CE plus 1 inch, cut the edge of the paper at F. On the edge of the cloth measure up from F 3 to 4 inches for the leg seam, and mark this point G. Connect A and G and B and G as shown in the illustration. This pattern represents one leg of the pair of drawers.

LESSON 92.

Problem.—To prepare some typical cereal breakfast foods.

Points to be brought out.—The value of the fireless cooker in the preparation of cereals. Cereals vary in composition according to the kind and part of grain used.

References.—U. S. Dept. Agr., Farmers' Buls. 105*, pp. 19–22; 237*, pp. 14–18; 249, and 316*, pp. 17–19.

Correlation.—Arithmetic: Calculate cost of individual servings of the various cereals.

LESSON 93.

Problem.—To prepare cornmeal mush, grits, hominy, and spoon bread.

Points to be brought out.—The grits or small hominy should be prepared by boiling as you would a very coarsely ground cornmeal. The large pearl hominy requires several hours at the boiling point in order to be sufficiently cooked. It lends itself especially well to preparation in the fireless cooker. Save any of the mush, grits, and hominy left for use at the next lesson.

References.—U. S. Dept. Agr., Farmers' Buls. 298 (Hulled corn, p. 21); 565 (Cornmeal mush, p. 10; Spoon cornbread, p. 19).

Supplementary topic.—Describe the construction of a homemade fireless cooker; of an improvised one for use in camping.

LESSON 94.

Problem.—To use left-over cereals.

Points to be brought out.—The mush or the grits from the last lesson may be reheated by frying. (Farmers' Bul. 565, p. 11.) Reheat the hominy in a skillet with a little fat. During the first part of the operation the mass may be stirred. Toward the last, the stirring is discontinued and a crust is allowed to form on the underside. In serving, this side is turned to the top of the dish. Polenta, an Italian dish, may be made from the mush by cutting it in slices in a baking dish and then sprinkling it with grated cheese, salt and pepper, and putting it in the oven until it is heated through and the cheese is browned. The variety of ways in which we may serve cornmeal and other corn products and the economy of cornmeal as a food should be emphasized.

References.—U. S. Dept. Agr., Farmers' Buls. 298, 558*, and 565.

Correlation.—English: List all the commercial cereal products, classify them in various ways. (Consult stores and catalogues.)

LESSON 95.

Problem.—To cut and seam the drawers.

Points to be brought out.—A fell made by machine on the right side of the garment gives a neat, strong finish. There is no special advan-

tage in the hand fell except where the seam is curved, and the machine will not make a flat finish.

Reference.—Same as in Lesson 90.

Correlation.—Arithmetic: Estimate the cost per hour of a sewing machine which costs \$25, lasts 20 years, and is used one hour a week.

LESSON 96.

Problem.—To wash woolen underwear.

Points to be brought out.—Strong alkalis dissolve wool. Weak solutions dissolve only small amounts of the fiber, causing it to contract or shrink. Use soap free from any excess of alkali. Very hot water or sudden changes from water of one temperature to that of a very different temperature is undesirable in the case of woollens. The character of the wool fiber is such that it tends to mat if rubbed too much.

Reference.—Rose, *The Laundry*, Cornell Reading Courses, 1 (1912), No. 11.

Correlation.—English: Write descriptions of the appearance of wool fiber under the microscope.

Supplementary topic.—Discuss different plans by which running water could be put into your house, or some other house of which you know, and their comparative cost. (Consult *Farmers' Bulletins* and catalogues.)

LESSON 97.

Problem.—To cook rice.

Points to be brought out.—In serving rice as a vegetable we wish to have the grains separate rather than in a gummy, pasty mass. This is accomplished by thorough washing to remove any adhering particles of starch, cooking rapidly in so much water that no stirring is necessary, or by cooking in a smaller amount of water in the double boiler, or the fireless cooker, and driving off the excess of moisture by heating after the cooking has been finished. These different ways should be tried in class. Unpolished rice is more nutritious than polished.

References.—Bulletin on Texas and Louisiana Rice, Pass. and Ind. Dept., Southern Pacific R. R., New Orleans, La.; Miriam Birdseye, *Rice and Rice Cookery*, Cornell Reading Courses, 3 (1914), No. 55.

Correlation.—English: Write stories of the way rice is grown. Name different rice dishes you have known; describe the making of one you like. To what country do we owe rice?

LESSON 98.

Problem.—To make placket and band on drawers.

Points to be brought out.—A good placket for drawers may be made with linen tape about three-fourths of an inch wide. (See *Handy and Pract. Libr.* [Missouri], Mo. Bul., 13 (1915), No. 2, p. 68.) If the waistband is to be stitched on, apply it to the wrong side first, so that

the final line of stitching will come on the right side. Instead of a band a flat, fitted binding or yoke about 2 inches wide may be used around the top.

References.—Same as in Lesson 90.

Correlation.—English: Write description of the different kinds of plackets and their uses. Compare cost of home-made and ready-made underwear. Is woman's home work worth money?

LESSON 99.

Problem.—Cereals and their value in the diet.

Points to be brought out.—Cereals contain all the necessary material for the formation of the new plant. The outer layers contain the largest proportions of mineral matter, and also of plant fiber; the inner sections are richest in energy-yielding starch.

Reference.—U. S. Dept. Agr., Farmers' Bul. 249.

Correlation.—English: Look up the countries in which the different cereals are grown and list them. Could any new cereal be introduced into your community?

LESSON 100.

Problem.—To finish the bottom of the drawers, make buttonholes and sew on buttons.

Points to be brought out.—Finish the bottom of the drawers in the same way as was done with the neck and sleeves of the gown. The traditional finish, a ruffle, is not only more work in making and difficult to launder, but is objectionable in that it gives an excessive amount of fullness at a point where fullness is not desirable.

References.—Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2, pp. 70, 71; clothing text.

Correlation.—English: Discuss simplicity in dress. How far is the elaborateness, which means extra work, justifiable in woman's dress?

LESSON 101.

Problem.—Wash a wool sweater.

Points to be brought out.—A neutral soap must be used, since an excess of alkali injures the fiber. The water used should not be too hot, and the successive waters should be of uniform temperature, for rapid expansion and contraction of the fibers tend to cause felting and shrinking. Too much rubbing also tends to felt or mat the fibers.

Reference.—Any good book on home laundry work.

Correlation.—English: Find cost for power-driven washers of various types—cost per week, (Consult catalogues for laundry equipment.)

LESSON 102.

Problem.—To prepare tapioca, macaroni, and spaghetti.

Points to be brought out.—These are often prepared in an unappetizing way. We should aim to season them well and not allow them

to become too dry. Macaroni should be cooked until tender in boiling, salted water. A good way to serve it is to put layers of the boiled macaroni in a baking dish with cream sauce and cheese between, cover with buttered bread crumbs, and bake.

References.—Textbook on foods; any good recipe book.

Correlation.—English: Write description of the process of manufacture of these cereal products.

LESSON 103.

Problem.—To select a design and pattern for a princess slip or a one-piece garment to take the place of corset cover and skirt. To determine the size required.

Points to be brought out.—This furnishes a good opportunity for the discussion of the value of patterns and the means of determining the size needed. Two or three sizes should be selected according to the variations in the measurements of the different members of the class.

References.—Current fashion magazines. Reference in Lesson 90.

Correlation.—Arithmetic: Estimate in advance the amount of material necessary and the cost; then keep a record of money and time actually spent.

LESSON 104.

Problem.—To cook peas, beans, lentils, and cowpeas.

Points to be brought out.—Beans and peas soften more quickly when cooked in soft water than when cooked in hard water, for the calcium in the hard water unites with some of the protein in the peas and beans to form a hard compound. It is sometimes possible to soften water by means of baking soda, but since the cook can not easily know how much soda is needed for the water in question, and since the soda may injure the flavor of the food, it is perhaps better to soften the water by boiling it previously if the character of the hardness permits of its being remedied in this way, or to use rain water.

References.—U. S. Dept. Agr., Farmers' Buls. 121; 256, pp. 21-27; 559.

Correlation.—Chemistry: Action of soda on hard water. English or agriculture: Discuss a plan for a vegetable garden for your own homestead.

LESSON 105.

Problem.—To adapt the pattern to the individual girl and cut the princess slip.

Points to be brought out.—Each girl should cut a duplicate of the pattern which is nearest her size and adapt it to her measures. The slip should be carefully fitted before seaming on the machine, and any necessary corrections made in the paper pattern.

Reference.—Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2, pp. 53–57.

Supplementary topic.—Make an inventory of your own wardrobe, with costs, for your own information.

LESSON 106.

Problem.—To fit and seam the princess slip.

Points to be brought out.—French or felled seams are the most satisfactory. For the back either the hemmed or the faced placket may be used since either fits smoothly.

Reference.—Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2, p. 68.

Supplementary topic.—Child labor and the cotton industry, on the plantation and in the mill.

LESSON 107.

Problem.—To cook legumes in any special way.

Points to be brought out.—Legumes are not to be scorned. A little care in their preparation makes them valuable and appetizing additions to the dietary.

References.—U. S. Dept. Agr., Farmers' Buls. 121; 256, pp. 21–27; and 559.

Correlation.—English: Write on the raising of some one legume which your family has not usually raised.

LESSON 108.

Problem.—To discuss the value of the legumes in the diet.

Points to be brought out.—Legumes are valuable as a source of protein in the diet and on this account are useful as a substitute for meat. They also contain mineral salts which the body needs.

References.—U. S. Dept. Agr., Farmers' Buls. 121; 256, pp. 21–27; and 559.

Correlation.—Arithmetic: Calculate the cost of definite amounts of protein obtained from one of the legumes. Compare with the cost of equal amounts of protein from meat.

LESSON 109.

Problem.—To make soups from peas and beans. Use either water or skim milk as the liquid.

Points to be brought out.—Judicious seasoning and the addition of fat are necessary in order to develop a desirable flavor. These soups, especially those prepared with milk, have a high nutritive value.

References.—U. S. Dept. Agr., Farmers' Buls. 256, p. 25; and 559, p. 11.

Correlation.—Agriculture: The relation of legume crops to renewal of soil fertility. Plan a rotation of crops including a legume. What legume crops have been raised in your community? What would be good for your farm?

LESSON 110.

Problem.—Final fitting of the princess slip and turning of the hem.

Points to be brought out.—The bottom of the skirt should be protected in some way to prevent wearing. The traditional way is with a dust ruffle, but this is not always desirable when worn with a narrow dress skirt. In that case it may be better to use a small, heavy machine-embroidered scallop or the zigzag braid which comes for that purpose.

Supplementary topic.—What is the proper length of skirt for an infant, for a girl of 8 years, of 14 years, an adult woman? Should skirts ever trail on the ground? What is the ideal width for a skirt from the standpoint of comfort, regardless of style?

LESSON 111.

Problem.—Mending.

Correlation.—English: Plan and describe a systematic and orderly way of caring for mending supplies and materials, as in a special work table with drawers having partitions, or a set of boxes or baskets.

LESSON 112.

Problem.—Composition of nuts and their value in the diet.

Points to be brought out.—Nuts are rich in protein and fat and these nutrients are present in a form that is fairly easily assimilated. Since they are concentrated foods they should not be used in quantity with a heavy meal, and only in combination with more bulky foods. Nuts are used as an ingredient of salad, in soups, as a stuffing for poultry, in the making of desserts, and in many other ways.

Reference.—U. S. Dept. Agr., Farmers' Bul. 332.*

Correlation.—Geography: Look up countries in which the typical nuts are raised. Which nuts are adapted to your own locality? How could you secure new varieties for your own homestead? (See catalogues.)

LESSON 113.

Problem.—To finish the neck and sleeves of the princess slip, make buttonholes and sew on buttons.

Points to be brought out.—Whether the neck of the slip should be finished with fullness or flat depends partly on whether it is to be worn under a loose or a tight-fitting garment. If it is to be worn directly under a thin material it should be high enough in the neck and broad enough over the shoulders to cover the other undergarments.

Correlation.—Arithmetic: Compute actual money and time expended in making slip and compare with estimate (Lesson 103).

LESSON 114.

Problem.—To review vegetable foods in general.

LESSON 115.

Problem.—To review the sewing work and score the underwear made.

Suggested score.—(This is adapted from a score given by Miss Mary L. Matthews, Extension Bulletin 23, Purdue University, Lafayette, Ind.)

Score card for underwear.

I. Structure:	Points.
(a) Suitability of design to use.....	10
(b) Choice of material.....	5
(c) Choice of trimmings.....	5
(d) Width and evenness in size of:	
1. Seams.....	2
2. Hems.....	2
3. Tucks.....	2
4. Bands and trimmings.....	2
5. Gathers. (When there are no gathers let these points go under 4).....	2
(e) Accuracy of cutting.....	10
II. Stitches:	
(a) Appropriateness.....	5
(b) Evenness and neatness.....	15
(c) Size.....	10
III. Finishing:	
(a) Buttons and buttonholes.....	10
(b) Fastening of thread ends.....	5
(c) Removal of bastings.....	5
IV. General appearance:	
(a) Cleanliness of work.....	6
(b) Pressing.....	4
Total.....	100

LESSON 116.

Problem.—To study insects as a means of transmitting disease. To plan and inaugurate a campaign against the fly.

Points to be brought out.—The fly may distribute disease germs to food. By killing the first flies that appear before they have had a chance to breed, it is much easier to keep their numbers down.

References.—U. S. Dept. Agr., Farmers' Buls. 155*, 412*, p. 11; and 679.

Correlation.—English: Write a story of how a fly helped spread a disease. Make a plan for controlling flies on your farm and for eradicating mosquitoes.

LESSON 117.

Problem.—Soft cooking of eggs. Cook eggs in boiling water for 3, 5, 7, 14, 30, and 60 minutes. Cook eggs for the same lengths of time in water which is boiling when the eggs are introduced, but which is set aside and not allowed to boil after the introduction of the eggs. Break the eggs and compare the consistency.

Points to be brought out.—Eggs coagulate at a temperature below the boiling point of water. When cooked in boiling water the outside is overcooked and in many cases the yolk is not completely heated through.

Reference.—Eggs and Their Value as Food, U. S. Dept. Agr., Bul. 471.

Correlation.—English: Write a story of a girl who made money to go to college by keeping poultry.

LESSON 118.

Problem.—Putting away winter clothing. The best means of preventing moths.

Points to be brought out.—The eggs from which moths develop may be present. These must be killed or removed before the clothes are put away, for they may find in the packed clothes ideal conditions for their development. Since it is difficult to be sure that all moth eggs are removed, the clothing is usually packed under such conditions as to retard their development.

References.—U. S. Dept. Agr., Bur. Ent. Circ. 77; Farmers' Bul. 659.

Correlation.—English: The life history of the moth. What other insect pests has the housewife to fight? (See U. S. Dept. Agr., Farmers' Buls. 626, 627, 658, 679, and 681.)

LESSON 119.

Problem.—Apply the principles worked out in Lesson 117 by preparing poached eggs on toast, scrambled eggs, and eggs in any other way that the girls wish to try.

Points to be brought out.—A more digestible and palatable product results when the cooking process is carried out at a temperature below that of boiling water.

References.—Textbook on foods; any good recipe book.

Correlation.—Physiology: Show in what ways the method of cooking eggs may affect their digestibility.

LESSON 120.

Problem.—To select a design for a simple skirt and draft the foundation skirt pattern.

Points to be brought out.—A well-fitted foundation skirt pattern can be adapted to various skirt designs. Such a pattern is better suited to an individual than stock sizes of the commercial pattern.

Reference.—Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2, pp. 34-37, 53-55.

Correlation.—English: Discuss clothing as an expression of personality.

LESSON 121.

Problem.—To make a flytrap. Discussion of best methods of eradicating flies.

Points to be brought out.—The best method of eradicating flies is by cleaning up the filthy places in which they breed. We may "swat" the flies, catch them in traps, or we may prevent their access to any water supply except one that contains poison. Screening of houses is an absolute necessity in fly-infected communities.

References.—U. S. Dept. Agr., Farmers' Buls. 133*, p. 25; 532*, p. 22; 679.

Correlation.—English: Make a list of the wood-working tools which every housekeeper should have at hand, with prices. (See catalogues.)

LESSON 122.

Problem.—The composition of eggs and their value in the diet. Effect of cooking on their digestibility.

Points to be brought out.—Eggs are valuable as a source of protein and mineral matter in the diet. The digestibility depends not only upon the temperature at which they are cooked, but also upon the flavor and the ease and fineness of division.

References.—U. S. Dept. Agr., Office Expt. Stas. Bul. 143; Langworthy, Eggs and Their Value as Food, U. S. Dept. Agr., Bul. 471.

Correlation.—Arithmetic: Calculate the cost of protein food as obtained in eggs at the prices customary at different seasons of the year.

LESSON 123.

Problem.—To adapt the pattern of the foundation skirt to the design selected and to cut skirt.

Points to be brought out.—The foundation skirt may easily be modified in accordance with the different designs.

Reference.—Same as in Lesson 120.

(Drafting is advisable wherever possible, but if necessary a commercial pattern may be used instead.)

Supplementary topic.—Make a list of the articles of clothing desirable for a girl of 10 years on a farm.

LESSON 124.

Problem.—To make an omelette.

Points to be brought out.—An omelette is an egg mixture cooked in a pan over the flame. It is usually made light by the expansion of air incorporated in the white. Milk is added to make the mixture more tender, but should not be added in a proportion larger than one tablespoonful to each egg because the mass becomes too liquid. Cream sauce may be added in amounts up to one-third cup for each

egg. In cooking, the aim should be to heat the mixture sufficiently first to cause the incorporated air to expand, and then to coagulate or "set" the albumen which constitutes the walls of the air-containing cells. Heat must be applied gradually, else the underneath portion is overcooked before the mass is heated through. The top should not be browned. If the top is not completely cooked, it may be dried by placing the pan in the oven about 30 seconds.

References.—Textbook on foods. Any good recipe book.

Supplementary topic.—Name of the varieties of poultry of which you have heard. Which kind would you prefer for a family flock? Which, if you were keeping them for commercial profit?

LESSON 125.

Problem.—To baste and fit the skirt.

Points to be brought out.—The first skirt should be fitted carefully and the necessary corrections made on the pattern. If the skirt is to be French seamed, be sure the seams are basted on the right side with edges of the proper width.

Reference.—Same as in Lesson 120.

LESSON 126.

Problem.—To wash table napkins and remove stains.

Points to be brought out.—A stain is caused by the deposition of some material. Since the action of hot water and soap sometimes renders insoluble materials which are in the beginning soluble, it is wiser to remove all stains possible before commencing the washing operation.

In order to remove a stain a solution must be found in which the stain is soluble and which is not harmful to the fabric. Make a list of the reagents which should be present in every laundry for use in the removal of stains. Make a list of the ordinary stains occurring on household textiles with a corresponding list of the reagents which will remove these stains.

Reference.—Rose, *The Laundry*, Cornell Reading Courses, 1 (1912), No. 11, pp. 128-132.

Supplementary topic.—Describe the growing of flax and the making of linen. Discuss ways of making the table attractive when linen can not be afforded. Cost of paper napkins; of oilcloth. Discuss the use of flowers upon the home table.

LESSON 127.

Problem.—To make a sponge cake.

Points to be brought out.—True sponge cake contains both the white and the yolk of the egg. It is made light by the expansion on heating of the air incorporated in the egg white. Lemon juice is added for flavor and for the effect that the acid has on the texture. The

cake may be cheapened by substituting for some of the eggs a liquid, preferably water, and baking powder, in the proportion of one-half teaspoonful of baking powder and two and one-half tablespoonfuls of water for each egg. The general proportions for sponge cake are one-fourth cup of flour and one-fourth cup of sugar to each egg, or equal amounts of egg, flour, and sugar, since each egg is supposed to measure one-fourth cup. Bake in an oven at 175° C. (350° F.).

References.—Textbook on foods. Any good recipe book.

Correlation.—Physics: Expansion of air.

Supplementary topic.—Discuss the omission of elaborate desserts in a home in which the mother is overworked. List desserts suitable for different occasions during the year.

LESSON 128.

Problem.—To seam the skirt.

Points to be brought out.—The kind of seams used should be adapted to the material. If it is heavy, the seams should be tailor-stitched and the edges overcast or bound. If it is light, French seams may be used.

References.—Same as in Lesson 120.

Supplementary topic.—Discuss means of keeping the father's and brother's clothing neat and attractive—proper ways of folding and hanging, coat forms, pressing, "dry cleaning," etc. Neatness in working clothes. How often should overalls be washed?

LESSON 129.

Problem.—To determine the reasons for the great fluctuations in the price of eggs. Preservation of eggs.

Points to be brought out.—Large numbers of eggs are lost through inefficient handling in the homes and on the farm. Infertile eggs keep very much longer than the fertile ones. Water glass is very useful as a preservative. Evidence seems to point to the spring egg as the best to preserve.

References.—U. S. Dept. Agr., Farmers' Buls. 103*, p. 17; 273*, p. 17; 296*, p. 29; 353*, p. 14; Production and Handling of Market Eggs, Mo. State Poultry Expt. Sta. Bul. 5 (1915).

Correlation.—Arithmetic: Calculate the increase in price of 50 dozens of eggs when held over from April until December, allowing for cost of water glass, crocks, and time necessary in handling. How many eggs might well thus be preserved for your family? How much would be saved by using preserved eggs and selling your fresh eggs in winter?

Supplementary topic.—Describe a plan for a cooperative egg-shipping association; the shipping of eggs by parcel post. U. S. Dept. Agr. Farmers' Bul. 656, Community Egg Circle.

LESSON 130.

Problem.—To put the placket in the skirt and sew on the band.

Reference.—Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2.

Supplementary topic.—Is it better to buy good fabrics for women's dresses and men's suits expecting garments to last several years, or to buy unsubstantial material and discard it after a short time?

LESSON 131.

Problem.—To iron linen by hand and in a mangle. Comparison of the amount of time used in each case. Suggestions for substitutes for ordinary table linen which can be cared for with less expenditure of time and energy.

Points to be brought out.—Much time can be saved by putting table linen through a mangle rather than ironing it by hand. Doylies and table mats require less time to launder successfully than the larger pieces.

Reference.—Any good book on home laundry work.

Correlation.—Arithmetic: Calculate amount of time saved by the use of a mangle in the laundry work for a family of six. How long will it take a mangle to pay for itself? (See catalogues.)

LESSON 132.

Problem.—To make angel and sunshine cakes.

Points to be brought out.—An angel cake differs from a sponge cake in that we use the whites only and none of the yolks of the eggs. The proportion is in this case as before, equal measures (by volume) of egg white, sugar, and flour. One white is approximately one-eighth of a cup. Since the egg white contains so large a proportion of water, we add our acid in this case in the form of a solid, using cream of tartar instead of lemon juice, and substituting some other form of flavoring.

A sunshine cake comes just halfway between the angel cake and sponge cake. In it we use both the white and the yolk of the egg, but the number of whites used is larger than the number of yolks. The use of these cakes is to be encouraged, especially during the time of the year when eggs are cheap and abundant.

References.—Any good recipe book. Textbook on foods.

Correlation.—Arithmetic: Calculate cost.

Supplementary topic.—What do similar bakers' cakes cost? Why do we still bake cake at home? Is this wise if the mother is overworked?

LESSON 133.

Problem.—The preparation of custards. (This lesson should follow immediately the lesson on angel cake in order to utilize the egg yolks left over from the cake.)

Points to be brought out.—The value of starch and flour as a means of thickening liquid has already been studied. The object of this lesson should be to give the students some idea of the value of the egg as a means of thickening and of the proportion in which it should be used. We have two classes of custards—soft and hard, depending upon the proportion of egg used and the method of cooking. Custards should always be cooked over or in hot water. “Boiled custard” is a misnomer. It should be called “soft.”

References.—Textbook on foods. Any good recipe book.

LESSON 134.

Problem.—To finish the skirt.

Points to be brought out.—The bottom may be either hemmed or faced. All loose ends of thread should be carefully fastened.

References.—Textbook on clothing. Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2, pp. 71 and 72.

Supplementary topic.—Discuss ways of putting away skirts so that they shall keep their shape; plan a method adapted to your own home.

LESSON 135.

Problem.—To press and score the skirts, and review the problems involved in making them.

Reference.—Univ. Mo. Bul., 15 (1914), No. 7.

Correlation.—English: The score-card method of judging may be applied to any subject the quality of which depends on several factors. Secure score cards for sanitary conditions in dairy, for judging stock (U. S. Dept. of Agriculture), for jams, jellies, etc.

LESSON 136.

Problem.—To wash a colored dress, preferably one which is in danger of fading.

Points to be brought out.—Colors fade on account of (1) the long continued action of water and soap, (2) the use of strong acids or alkalis, and (3) exposure to strong sunlight. In order to prevent the fading of colors we avoid so far as possible the above conditions, and in the case of especially fleeting dyes we attempt to set the color. Setting the color is accomplished by the use of a mordant, that is, a material which will bring about a stronger union between the cloth and the dye. Make a list of the chemicals most frequently used in setting colors, the proportion, and the colors for which they are used (Rose, *The Laundry*, p. 139). A sample of the material whose color is to be set should be tested in each of the mordants and then washed. From the results one can determine which is the best to use. Apply this at the next lesson in the washing of the dress, observing all the above suggestion.

References.—Rose, *The Laundry*, Cornell Reading Courses, 1 (1912), No. 11, p. 139; any good book on home laundry work.

Correlation.—English: Discuss clothing waste from cheap dyes; draw conclusions from personal experience and observation.

LESSON 137.

Problem.—To make a cheap sponge cake.

Points to be brought out.—By the substitution of water and baking powder for part of the egg we may cheapen the sponge cake. Custards may be cheapened by the substitution of flour for part of the egg. Angel cakes and sunshine cakes may be cheapened in the same way as the sponge cake.

References.—Textbook on foods. A good recipe book.

Correlation.—English: Explain the basis of the substitution and calculate how much is saved by it.

LESSON 138.

Problem.—General review of egg cookery.

References.—U. S. Dept. Agr., Office Expt. Stas. Bul. 43; Farmers' Bul. 471.

Supplementary topic.—Discuss: How far can the average southern homestead produce to advantage all the foodstuffs required for its own table? How can a larger variety be produced than at present?

LESSON 139.

Problem.—To plan a waist. Each girl should submit a design. These should be discussed in class and modified if necessary.

Points to be brought out.—A desirable design is simple and does not involve too much work.

References.—Textbook on clothing; current fashion journals.

Correlation.—Arithmetic: Estimate the probable cost of the waist planned, in both money and time.

Supplementary topic.—Discuss simplicity in dress and indicate desirable standards of simplicity, taking into account cost, durability, expense and labor of laundering, etc.

LESSON 140.

Problem.—To draft a waist pattern.

Points to be brought out.—In drafting we are aiming to get a pattern adapted to the measurements of the individual. The system used should be as simple and rational as possible. Try the draft before using to be sure that it will work. Be sure that you understand each and every step and know the reason for each one. The simplest draft with the fewest arbitrary directions is the best. Go over it with the class and be sure that they understand each and every step

before starting the work. In this way drafting can be made a rational process and not a mere following of directions. Let the girls work in groups of two for taking measures and fitting.

References.—Textbook on clothing; any reliable and simple drafting system for a waist.

Supplementary topic.—Investigate the condition of the various types of workers in clothing establishments near your home, e. g., workers by the day, custom workers with their own shops; compare the business arrangements, wages, etc. Is there need of improvement?

LESSON 141.

Problem.—Ironing of a colored dress. Pressing cotton and linen dresses.

Points to be brought out.—The iron should not be too hot. The dress should be ironed on the wrong side. Frequent pressing improves the appearance of cotton and linen dresses.

Reference.—Rose, *The Laundry*, Cornell Reading Courses, 1 (1912), No. 11, pp. 127 and 145.

Correlation.—English: Discuss proper storage of clothing as a means of reducing amount of pressing necessary; describe desirable equipment for ironing for your own home, e. g., the best kind of board. (See catalogues.)

LESSON 142.

Problem.—Finish and correct waist drafts, checking every measure carefully. Cut out in cheap lining material to be fitted.

Points to be brought out.—Exactness is the most important factor in successful drafting. All the measures should be checked up to be sure that they are accurate. As a final precaution, a waist should be cut from cheap material and fitted. This fitted pattern is the one to be kept.

Correlation.—English: Discuss exactness or precision in workmanship as needed by the housekeeper in sewing, in cooking, in care of sick, etc.

LESSON 143.

Problem.—Preparation of cream tomato soup and a cup of chocolate or cocoa.

Points to be brought out.—Acid curdles milk. This effect is hastened by heating. It is retarded by thickening either the tomato juice or the milk before combining them or seems to be because the thickened liquid holds in suspension any curd that may be formed. Therefore, in order to prevent the curdling of tomato soup we thicken either the milk or the tomato juice with the requisite amount of flour and combine them at the proper temperature for serving. The use of soda to

neutralize the acid is not recommended since it may destroy the delicate flavor of the tomatoes, and, if used in too large quantities, is likely to cause indigestion. It is almost impossible to tell when just the correct amount has been used, since the acidity of tomatoes varies to such an extent. In boiling the milk to make the cocoa, the scum usually formed on the surface can be prevented by stirring the milk or by boiling it in a covered vessel.

References.—Textbook on foods. Whipping cream, U. S. Dept. Agr., Farmers' Bul. 384*, pp. 19-22.

Correlation.—English: Describe the growth and manufacture of cocoa and chocolate; list the different brands available in your neighborhood, with prices. (Consult stores and catalogues.)

LESSON 144.

Problem.—To fit the waist pattern.

Suggestion.—The pattern cut in Lesson 142 should be very carefully fitted and trimmed off at the neck and sleeves. When it is correct in all details mark the line of the seams, rip the pattern apart and trim the edge evenly, allowing one-half to one-fourth an inch for seams. This is sufficient to admit of French seams being made. Be sure that the seams are evenly trimmed. Cut the pattern in half down the center front and the center back. (It may seem a waste of time to draft and fit a pattern in this way, but it will more than repay you in the amount of time saved later.)

Correlation.—English: Make the briefest possible list of patterns which could be adapted to the cutting of the garments made in your own family. How could you best store patterns systematically?

LESSON 145.

Problem.—To prepare cottage cheese. It may be used in making sandwiches for a picnic for which the rest of the luncheon may be planned in class.

Points to be brought out.—The curd is separated from the whey more completely if the mixture is slightly heated. This separation is accomplished by heating to 40° C. (104° F.). Heating to a higher temperature than this toughens the curd. A picnic luncheon should be appetizing, abundant, and easily carried.

References.—U. S. Dept. Agr., Farmers' Buls. 202*, p. 28; 430*, p. 10.

Correlation.—English: Write an account of this picnic. List the places available for neighborhood picnics near your home. Is there a place on your farm where you could arrange an outdoor fireplace for occasional family picnics? Describe plans for such a picnic.

LESSON 146.

Problem.—To plan the different steps in the family washing.

Points to be brought out.—Tuesday is the best day for washing, as this leaves Monday free for the mending, and gives opportunity for putting the clothes to soak on Monday night, if soaking is considered necessary. The steps in washing should be worked out in an orderly manner. Let each girl do her washing one week, treating it as she would a family washing and giving a definite reason for each step.

Reference.—Rose, The Laundry, Cornell Reading Courses, 1 (1912), No. 11, p. 132.

Correlation.—English: Describe a plan for using a town laundry by means of parcel post. Work out the cost of your average family washing, including post charges to nearest laundry. (N. B.—Some southern families send laundry to distant city laundries.)

LESSON 147.

Problem.—To make rennet custard, and look at milk and cream under the microscope.

Points to be brought out.—Rennet is an enzym and acts best at the temperature of the body. It is killed if heated to the boiling point. If added to milk which has previously been heated and cooled, it either does not clot, or forms a curd which is less dense, according to the length of time the heating has been continued. On this account, when chocolate is to be added it is better to melt it in a small portion of the milk and then combine with the remainder. The fat is present in the milk in minute droplets. Such a mixture is called an emulsion.

References.—Textbook on foods; U. S. Dept. Agr., Farmers' Bul. 457*, p. 21.

Correlation.—Physiology: Study of enzymes and the conditions under which they act best.

LESSON 148.

Problem.—To adapt the drafted pattern to the waist planned.

Points to be brought out.—By slight changes the simple shirt waist draft can be adapted for use with more complicated designs. Tucks should be put in and allowance made for any fullness before the waist is cut out. Where the design is at all complicated a paper or cloth pattern should be cut first and tested by holding up to the figure.

References.—Textbook on clothing. Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2.

Correlation.—English: Criticize the waists from the standpoint of artistic design.

LESSON 149.

Problem.—Buttermaking.

Points to be brought out.—In churning we are aiming to control conditions which make the small globules of fat coalesce.

References.—Farm Buttermaking, U. S. Dept. Agr., Farmers' Buls. 92*, p. 23; 133*, p. 30; 186*, p. 29; 384*, p. 22; 412*, p. 28; 541.

Correlation.—English: Discuss cream separators, those driven by hand and by gasoline engines; costs. Similarly discuss churns. (See catalogues.) Is it possible in your community to sell or ship milk? Cream? How could a market be secured? Has a cooperative creamery been discussed? (Farmers' Bulletins.)

LESSON 150.

Problem.—To fit and seam the waist, joining the seams with beading.

Points to be brought out.—A convenient way to use beading in a seam is as follows: Baste and fit the seam as usual. Mark carefully the line where the beading is to come, and rip the seam apart. Lay the right sides of the insertion and of the waist together, baste and stitch along the line of the seam so that the stitching comes exactly at the edge of the embroidery. The stitching will not show on the right side of the waist. Face back with the plain muslin at the side of the embroidery. This makes a neat and dainty finish for thin waists. It is quite as effective as when the beading is rolled and whipped in by hand, and is much more durable.

Reference.—Textbook on clothing.

Supplementary topic.—What garment could you make for your father—a cravat, a dressing gown, slippers, a lounging jacket? Do proper clothes help people to rest, to play?

LESSON 151.

Problem.—To wash a soft silk waist.

Points to be brought out.—The same care should be taken as in the case of wool. While the fiber is not so easily affected by alkali or acid, it is usually more fragile, and must be handled carefully.

Reference.—Rose, The Laundry, Cornell Reading Courses, 1 (1912), No. 11, p. 140.

Correlation.—English: Stories of silk culture. Can it be introduced into the South?

LESSON 152.

Problem.—To determine the proportion of cream in ordinary milk, the percentage of fat in cream, and to make ice cream.

Points to be brought out.—A great variety of flavors is possible in ice creams. Fillers are used to add to the body of an ice cream. Fillers are starch, eggs, and pastry products. A binder prevents

crystallization on standing. Binders are gelatine and vegetable gums. The percentage of fat in ordinary cream should be determined.

References.—Bacteriological Study of Ice Cream, U. S. Dept. Agr. Bul. 303; Ice Cream, Vermont Expt. Sta. Bul. 155.

Correlation.—Physics: Use of ice and salt in making ice cream. Latent heat. Kinds and costs of ice cream freezers. (See catalogues.) If you have a gasoline engine at home, how could it be attached to turn the freezer? Make drawing. Milk tester; cost. (See catalogues.)

LESSON 153.

Problem.—The value of milk as food and the care of milk in the home.

Points to be brought out.—Milk is provided as food for the young. It contains all the food nutrients but they are not present in the proper proportion for an adult. It is food for bacteria as well as human beings, so it must be especially protected against their entrance. They cause the souring of milk and in other ways render it unfit for human food.

References.—U. S. Dept. Agr., Farmers' Buls. 363 and 413.

Supplementary topic.—Different breeds of cows. Which do you prefer for a family cow? Which for a money-making herd? The household refrigerator, construction and cost. (See catalogues.)

LESSON 154.

Problem.—To make the sleeves for the waist and continue the work on it.

Points to be brought out.—The most difficult thing in fitting a sleeve is to adjust the shape and fullness at the armhole. Sometimes sleeves are cut in one piece with the waist. This saves work, but it is hard to fit them so that they shall not bind across the upper arm nor be clumsy under the arm.

References.—Handy and Pract. Farm Libr. [Missouri], Mo. Bul., 13 (1915), No. 2, pp. 45–48; any fashion magazine.

Correlation.—Arithmetic: Calculate the difference in time and material required in making waists with different types of sleeves.

LESSON 155.

Problem.—To finish the neck of the waist.

Points to be brought out.—Waists without collars are comfortable and usually becoming. The neck should be neatly finished. A collar should not be so tight as to constrict the neck in any way.

Reference.—Textbook on clothing.

Correlation.—English: Describe women's neckwear in colonial times. Do you accept comfort as a fundamental requisite in selecting or designing clothing? Discuss this point.

LESSON 156.

Problem.—To wash and clean ribbon.

Points to be brought out.—The ribbons should not be rubbed. They should not be wrung out but dried between towels. A dry cloth should be laid over them in ironing.

Reference.—Rose, *The Laundry*, Cornell Reading Courses, 1 (1912), No. 11, p. 141.

Supplementary topic.—Discuss the place of decoration in dress. Is it the first requisite in clothing?

LESSON 157.

Problem.—The preparation of salad dressings.

Points to be brought out.—Salad dressings usually combine fat with an acid flavor. The fat separates from any liquid unless special precautions are taken to keep the two in combination. We combine them either as a temporary emulsion, or a permanent emulsion, or we keep the fat in suspension by thickening the liquid to which it is added with flour or with egg, or with both. Samples of all the typical dressings should be made. In some sections there is a great prejudice against the dressings made with oil. These should be made, but no one should be forced to eat them or even taste them. The students should understand that making mayonnaise with oil is just the reverse of churning.

References.—Textbook on foods; any good recipe book; U. S. Dept. Agr., Office Expt. Stas. Bul. 245, pp. 20-26.

Correlation.—English: Look up meaning of "emulsion." Study principles of homogenizing milk and butter to form cream.

LESSON 158.

Problem.—To finish the waist. Sew on buttons and make button-holes.

Points to be brought out.—A neat finish adds materially to the appearance of a waist. To use pins instead of buttons and button-holes is an untidy habit.

Correlation.—Arithmetic: Calculate cost of waist and the amount of time spent in its construction. Compare with estimate of money and time cost in Lesson 139.

Supplementary topic.—Discuss how much a mother's time is worth—to herself, her family, and society.

LESSON 159.

Problem.—Use the salad dressings prepared during Lesson 157 to make a number of typical salads.

Points to be brought out.—All salads should be cool and contain some crisp material. The crisp materials should not be combined

with the dressing until just before serving. Materials which are not crisp should be marinated (mixed with vinegar and seasonings or with oil, vinegar, and seasonings awhile before serving and allowed to absorb the flavor). Distinguish between a light and a heavy salad and the place each should take in the meal.

References.—Same as in Lesson 157.

Correlation.—English: List the different salads of which you have heard. Discuss the place of salads in the regular family meal. Suggest salads for special occasions. Describe one you wish to try when you get home.

LESSON 160.

Problem.—Making and remaking of sashes and girdles. The ribbons washed in Lesson 156 should be used.

Points to be brought out.—A little ingenuity will enable one to freshen up last year's girdle or to make or trim one out of odds and ends of suitable material.

References.—Current fashion journals.

Supplementary topic.—Discuss the economic aspect of storage in carrying over clothing from one season to another. Plan a record book suitable for your own home to show what clothing is put away and just where it is packed, so that it can be quickly found as needed.

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CHARLES J. BRAND, Chief



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COOPERATIVE ORGANIZATION BY-LAWS.

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IMPORTANCE OF BY-LAWS.

The founders of every cooperative association should have a definite plan of action mapped out before the organization actively engages in business, as the lack of such a plan has resulted in the failure of many cooperative enterprises. The importance of the by-laws of a cooperative association is readily comprehended when it is realized that the purpose of the by-laws is to serve as a working plan for the organization. The relation of the by-laws to the organization resembles the relation of the specifications for a building to the finished structure. The blue prints furnish the builder with a graphic representation of the work to be done and this is supplemented by the necessary descriptive material, so that he knows before the building operations are commenced what each room is to be like and how the entire structure will appear when finished. Satisfactory results are not obtained when the plans furnished the builder are incomplete or inaccurate. A person about to erect a building does not obtain a photograph of a structure, the appearance of which pleases him, and expect the workmen to be able to build one like it with no other guide than this photograph. Organizations on the

other hand too often expect to obtain the desired results by merely providing a general set of by-laws, which do not go into the details of the form of organization or the method of conducting the business.

ADAPTATION OF THE BY-LAWS TO LOCAL NEEDS.

It is impossible to draw up a standard form of by-laws which will adequately meet the needs of all organizations, for certain features may be highly desirable for one organization and decidedly impracticable for another organization. Among the reasons for variation in the by-laws, the kind of business engaged in is important. Thus the regulations in the by-laws of a fruit-shipping association regarding the grading and packing of goods shipped are not applicable to the business of a creamery organization. Many other illustrations could be given.

Certain parts of the by-laws must be drawn to suit the form of organization. Thus an association with capital stock will have clauses relating to its stock, while a nonstock association must substitute other sections more particularly adapted to its form of organization. The size of organization also should be taken into consideration, because by-laws drawn to meet the needs of a small local association would have to be changed before they would suit a large organization. The general plan may be the same in both cases, but some of the details necessarily will differ. Thus, in a small organization with a selected membership, restrictions on the individual members may be observed, while in a large organization it would probably be impossible to enforce such restrictions.

Differences in the requirements of various locations must not be overlooked. Not only may the local conditions surrounding a co-operative creamery in Vermont differ from those of a similar plant in Texas, but the local conditions at one creamery may vary considerably from those at a plant only a few miles away. The questions of proximity to market, of competition, of the characteristics of the local population, and the kind of farming all must be considered.

The State law under which the organization is to be incorporated also influences the character of the by-laws. Some of the States have special laws providing for the formation of co-operative associations; in other States such associations are formed in accordance with the general incorporation laws. The State laws are far from uniform, and it is therefore important to ascertain the requirements of the laws of the State in which the association is being incorporated, in order that the by-laws may be drawn in accordance with the law.

IMPORTANCE AND ADVANTAGES OF INCORPORATION.

A co-operative association may be in the form of a voluntary unincorporated association or it may be incorporated under the laws of the State in which it is being formed, or those of some other State.

Associations of the former class are rather loosely organized and lack certain advantages which are gained by incorporation.

It is advisable for all organizations to incorporate, as this gives the organization a distinct legal status which can not be obtained otherwise. For instance, an unincorporated association is hampered in the matter of bringing suit as an organization, while the incorporated association is not subject to such disability. Another advantage of the incorporated over the unincorporated form is that, in the former, the individual liability of a member is fixed by statute and is usually limited to the amount which he has invested in its capital stock. In some States the unincorporated organization is considered a partnership. Where this is the case, the liability of the members is that of partners. In other States the unincorporated organization is regarded as an agent for its members. Where it is so held, the liability of the members is that of principals. Moreover, the incorporated association has a more definite form of organization than the unincorporated and the management thereof is placed in the hands of certain officers who can be required to account more strictly to the association. Among other advantages of incorporation may be included its value in providing an established business, the continued existence of which is assured more fully than that of the unincorporated. Incorporation usually prevents any dispute as to the ownership of the property held by the association.

The relation of the by-laws to the State incorporation laws has already been discussed, but it should be remembered that some of the States have more than one law for the incorporation of associations. In that event, it must be decided which law is the most desirable and the by-laws must be drawn accordingly. Articles of incorporation must be prepared before incorporation, but as the form of this procedure differs somewhat in the various States and the requirements can usually be ascertained from the Secretary of State or other official in charge of such matters, a suggested form for articles of incorporation is not included here.

SECTION 6 OF THE CLAYTON AMENDMENT.

In 1890 Congress passed the Sherman antitrust law, and in 1914 an amendment to the antitrust law, commonly known as the Clayton amendment, was passed. Section 6 of the Clayton Act is of particular interest to farmers' cooperative associations, because to a valuable extent it exempts such associations, provided they conform to its requirements, from the operation of the United States antitrust laws. Section 6 of the Clayton Act reads as follows:

That the labor of a human being is not a commodity or article of commerce. Nothing contained in the antitrust laws shall be construed to forbid the existence and operation of labor, agricultural, or horticultural organizations, instituted for the purposes

of mutual help, and not having capital stock or conducted for profit, or to forbid or restrain individual members of such organizations from lawfully carrying out the legitimate objects thereof; nor shall such organizations, or the members thereof, be held or construed to be illegal combinations or conspiracies in restraint of trade, under the antitrust laws.

It is obvious that if an association is to get the benefit of the section, it must comply with its requirements. It must be, first, a "labor, agricultural, or horticultural organization"; second, it must be "instituted for the purpose of mutual help"; third, it must be formed without "capital stock"; and, fourth, it must not be "conducted for profit."

As to the first requirement, there may be some difference of opinion regarding the membership of an agricultural or horticultural organization. Therefore it is safer that such an organization be composed only of persons engaged in or directly interested in farming. If it were not for this restriction it might be possible for a number of men engaged in some other line of business to organize, as an agricultural or horticultural organization, and claim the exemption provided by section 6 of the Clayton Act.

The second requirement provides that the organization shall be formed for mutual help; that is, it must be a cooperative association formed for the benefit of all its members and patrons and not of a few only. An organization formed or conducted with a different motive than for the purpose of mutual help can not come within the terms of the letter or the spirit of the section.

The third requirement is that the organization be formed without capital stock. Care must be taken to distinguish between the term "capital" and "capital stock." The qualification that an organization shall be without capital stock does not mean that it is not permitted to have any capital. Capital, or money needed to carry on the business, must be provided in some other way than by the issuance and sale of shares of stock. Capital stock is a common characteristic of the usual form of a profit-making corporation. The exclusion of capital stock serves further to differentiate organizations operating under section 6 from the ordinary profit-making corporation. It is obvious that the elimination of the capital stock feature removes much of the temptation to convert a cooperative organization into a profit-making enterprise.

The final requirement that the organization must not be conducted for profit, is in line with the second qualification, which provides that the organization shall be mutual. A distinction must be made between profits and savings. While under section 6 of the Clayton Act only such organizations as are not conducted for profit are given the benefits of the exemption from the operation of the United States antitrust laws, this does not mean that an organization meeting the requirements of this section is not permitted to effect

savings for its members. If the farmers, through cooperative collective bargaining, are able to effect economies in the matter of the sale and distribution of their products and the purchase of their supplies, to that extent each member is benefited by his proportion of the savings. If the organization takes out only what is necessary to cover the cost of operation and to provide adequate maintenance and reserve funds, and prorates the balance among the members and other patrons, in accordance with the amount of patronage which each has given the organization, it is believed that it is not being conducted for profit. In that case the so-called "patronage dividend" is only a refund to the member or patron of what the year's business experience has demonstrated to be an overcharge for services rendered the member. In this way the member makes savings only and the association never can make profit.

DEALING WITH NONMEMBERS.

If an organization handles the products of both members and nonmembers, and prorates any surplus it may accumulate among the members only, it is neither strictly mutual nor nonprofit and therefore does not measure up to the requirements of section 6. It follows that an organization transacting business with nonmember patrons must deal with such patrons on the same basis, with respect to its charges for services rendered and the distribution of savings effected, as it does with its members.

The test of mutuality and equality is to be found in the fact that the association does not charge the nonmember patron for services rendered to him more than the actual cost of such service, including his prorata part of all overhead expenses. This must be so, or otherwise a small group of farmers could organize an agricultural association, and, by doing a large business with nonmembers, make large profits for themselves. It is thus seen that section 6 makes it obligatory for every organization, desiring to secure its benefits, to treat all patrons alike, in the matter of charging for services rendered and distributing savings made.

The necessity for mutuality and equality, exacted by section 6, makes it highly desirable, if not obligatory, to have all patrons enrolled as members, as this removes any doubt which might otherwise exist as to whether or not the organization complies with the provisions of section 6. This presents a problem of some difficulty, for there may be instances where a nonmember desires to deal through an organization without becoming a member. The best way to meet the difficulty is to make it as easy as possible for anyone eligible to membership to unite with the organization. Then if such person does not want to become a member, it may be advisable for the association to refuse to act as his agent.

DIFFERENCES BETWEEN NONSTOCK AND STOCK FORMS OF ORGANIZATION.

The stock form of organization is the most common, but as this type does not meet the requirements of section 6 of the Clayton Act, added importance is given to the nonstock form, as far as agricultural associations are concerned. A fundamental difference between the two forms of organization is that, in one, stock must be purchased before a person is entitled to membership, while in the other it is customary to require a membership fee only.

In the stock form, there is no doubt about the financial interest of each member in the organization, while in nonstock organizations such interest can not always be so easily ascertained. When the necessary capital is secured exclusively by means of a membership fee, there is little difficulty in this particular; but if the money be obtained by levying assessments on the members in proportion to the business done for them by the association, it is impossible to know what each member's interest is unless complete records be kept.

The ordinary stock corporation distributes its profits in the shape of dividends on its shares of capital stock, while, in a truly cooperative organization having capital stock, any surplus to be divided is distributed, by first paying upon the capital stock a sum which represents a fair rate of interest on the money invested, and then dividing the balance in the form of what has been popularly called "patronage dividends," the latter distribution being based upon the amount of business transacted for the members by the organization. As a concrete illustration of these two methods, the following may be used: If a stock corporation with a capital of \$5,000, divided into 50 shares of \$100 each, does a business of \$100,000 and accumulates a surplus of \$1,000, above expenses and what is necessary for maintenance and reserve funds, a dividend of 20 per cent may be paid on each share; that is, every stockholder may receive \$20 for each share he owns. If this organization operates on the cooperative plan, it will pay a dividend which is equivalent to a fair rate of interest, say 6 per cent, on the capital invested in its stock, amounting to \$6 per share, or a total of \$300 in the form of interest, and then distribute the remaining \$700 in the form of so-called "patronage dividends," amounting to 70 cents on every \$100 of patronage. Nonstock organizations formed in accordance with the requirements of section 6 should distribute savings on a ratable basis of patronage.

Another common difference between the ordinary stock form and the nonstock form of organization relates to the voting power of the members. In the former it is customary to allow each member to vote according to the number of his shares, while in the latter all members have the same voting power. However, it should be

stated that truly cooperative organizations having capital stock now generally allow each member one vote only, regardless of the number of shares he may own.

FINANCING AND PERPETUATING NONSTOCK ORGANIZATIONS.

One advantage of the stock form of organization is that the sale of the shares provides the required capital. A nonstock organization must provide whatever capital it requires in some other way. Where only a nominal sum is necessary, this may be secured by means of a membership fee. If any considerable amount is required, that method may not prove feasible, because a large membership fee may make it difficult to secure members. Where a greater amount of capital than can be obtained from membership fees is required, it will have to be borrowed either from the members of the association or from an outsider. When it is desired to secure all of the capital from the members, the organization can make it a membership requirement for each member to loan the association a certain amount, or it may rely on loans being made voluntarily by members. One advantage of requiring all members to participate in such loans is that it creates a vital interest among them in the success of their organization, as they become directly concerned in its financial affairs. Moreover, reliance upon loans made voluntarily by the members necessarily introduces an element of uncertainty. This would be diminished or removed if each member assumed a fixed obligation to contribute his share of capital when called on. Where the money is borrowed outside of the membership, some security for the loans is usually required. In such case a joint note of the members or individual notes of the members may furnish the necessary security. The latter method is preferable, because it limits the liability of each person to the amount of his note.

When a supply of money is required for only a short period, as during crop-moving times, the plan of having each member give the association a negotiable, promissory, demand note for a certain sum and then using the notes as collateral in obtaining loans, has been employed with success. These notes may be used for three years, and at the end of that period, when the member's patronage of the association may have increased or diminished, new notes may be taken for a respectively larger or smaller amount and the old notes may be canceled. This is simply a method whereby the member loans a small portion of his credit to the association and does not actually pay out any money, unless the association should be unable to repay the loans thus secured. If the amounts of the notes are based on the amount of business likely to be transacted with the organization, each member will loan his credit in proportion to the use he expects to make of the organization. Obviously these notes

are not necessary in the case of organizations which are in a position to secure funds needed for short periods from other sources.

Whenever an organization borrows, provision must be made for paying interest and principal. In the case of short-time loans required to finance the organization during the marketing season, payment may be made from commissions deducted from the proceeds of sales of the products. Thus, in some lines of business considerable money is required during the rush season in order to make advances to the farmers for their products, as the association does not get the returns from the sale of the products until later. An organization operating on a safe margin should not experience any difficulty in meeting such obligations.

Similarly when loans are obtained to finance the erection of buildings, or the purchase of property, provisions for repayment should be made. Needs of this kind, however, can best be met in ways entirely different from those employed in supplying money for short periods. A method of obtaining money for such permanent purposes not infrequently followed by cooperative associations is to levy assessments on the members in proportion to the business done for them by the organization. Thus, in the case of a creamery organization, which borrowed the money necessary for building and equipping the plant, a special levy of 1 cent for each pound of butter fat handled was made in order to provide the money needed to repay the loan.

In case of a cooperative organization which secures from its own members the funds for making permanent improvements, it is sometimes argued that it is unnecessary to provide for repayment. There are strong reasons, however, for the association specifically to assume an obligation to return every contribution of this character. The membership of an association will gradually change, so that an organization which secured its capital from its original members, sometimes finds that many of the old members have dropped out and that new members, who have not contributed to the original expense of the association, have come in to take their places. On this account, unless some provision is made for the repayment of money obtained from the members, the time may come when all the members who have contributed will have withdrawn. Adequate provision, of course, should be made annually for depreciation in the value of the property.

Loans may be secured from members with the understanding that they will be repaid upon withdrawal from the association, or that they will be repaid at some stated time, or in installments.

One objection to allowing such loans to run until a member withdraws from the organization, is that there may be a number of withdrawals during one year and none during another year. Under these circumstances it is difficult to forecast how much money will be

necessary during any one year to repay retiring members. Another drawback to this method is that it results in an unequal financial interest of the members, as the remaining members will have to contribute to the amount due each withdrawing member, and, as a result the financial interest of the older members will be much greater than that of the newer members. Such an arrangement also would tend to put a premium on withdrawal from membership.

If each member is required to lend a certain amount to the association, such loans may be paid in annual installments, by levying an assessment on each member in proportion to the business conducted for him by the association, of sufficient size to provide the proper amount. When this is done each member should be given a statement at the end of each fiscal year, showing the amount he has contributed in this manner during the year. If arrangements be made to pay at the end of each year one-fifth of the original sums loaned to the association by each member, the entire amount will be paid in five years. The financial interest of all members in the association may be kept approximately equal by continuing the assessments and payments throughout the life of the association, so that, in fact, the loans are placed on a revolving basis. When this plan is followed, the amounts indicated on the yearly statement given to each member, after deducting the proper depreciation charge, will be paid five years from the time the statement is issued. Thus, the statements issued at the end of the first year will be taken up at the end of the sixth year, and so on. If it is desired, provisions can be made for the payment of interest on the money invested in this way. When this is done the assessments must be of sufficient size to take care of the interest as well as the principal.

As a concrete illustration of this plan, let it be assumed that a cooperative nonstock creamery association, composed of 100 members, requires \$5,000 to erect and equip the creamery. Each member lends \$50 to the association with the understanding that this amount will be repaid in annual installments so that the entire sum will be paid by the end of the fifth year, and that these loans are to receive 4 per cent interest per annum. A special assessment is levied on each pound of butter fat delivered to the creamery, of sufficient size to provide for the payment of the yearly installments on the loan, the interest, and also an additional amount to take care of depreciation. For this illustration, let it be assumed that 5 per cent per annum provides a sufficient reserve for depreciation. The total amount which will be provided annually by the special assessment then becomes \$1,450. Of this amount, \$1,000 is for the payment of the principal, \$200 is for interest, and the remaining \$250 is to provide a reserve fund for depreciation.

At the end of each year, each patron receives a statement or certificate of indebtedness which shows the amount he has contributed during the year, less his proportionate share of the interest and depreciation. In accordance with the plan previously outlined, these certificates will be taken up five years after they are issued. It will therefore be necessary to continue the special assessment for this purpose throughout the life of the association. In other words, \$1,450 will be provided annually in this manner.

It is important that sufficient provision for the creation of an adequate reserve fund for depreciation be made. Unless this is done the face value of the outstanding certificates soon will be greater than the assets of the organization. Of course, if provision for a reserve fund for depreciation is made in connection with the general operating expense, a charge for this purpose should not be included as a part of the special assessment.

The payment of interest on the certificates is desirable because the patronage of each individual is likely to fluctuate from year to year so that a member's financial interest in the organization may not always be exactly in proportion to the use he makes of the organization. The payment of interest also will give retiring members a return on their investment as long as they continue to hold a financial interest in the association.

An objection that some may have to offer, to the revolving plan of financing a cooperative association, is that it requires a complicated system of bookkeeping. This objection is not serious for it must be remembered that the same records will be required in order to distribute the patronage refunds, and the only additional labor will be in connection with the issuance and redemption of the certificates of indebtedness.

For some classes of business and for some organizations this plan of financing may not prove practicable because of the effect it may have on the immediate returns to the farmer for his products. In such instances it may be advisable to extend the period of repaying the loans, or some other plan may be found more feasible. Thus, an organization may be incorporated for 20 years and loans be secured for this period. When the 20 years have elapsed, a reorganization will be necessary and the new organization will be incorporated for another 20 years if the business is to be continued. The old loans will be paid up and the new organization will obtain new loans. Adequate provision for depreciation should be made so that the organization will be in a position to pay up old loans in full when due. A fair rate of interest should be paid on such loans.

SECTION 6 AND EXISTING ORGANIZATIONS.

Associations which are already engaged in business and which are not formed in accordance with the provisions of section 6 of the

Clayton Act, will have to change their form of organization and the manner of conducting their business, if they desire to obtain the benefits of the exemption provided by that section. No hard and fast rules for making this change can be laid down, as the exact procedure depends largely on the laws of the State in which the organization is incorporated. The first step should be to ascertain whether or not the State laws provide for the incorporation of organizations formed in accordance with section 6. If so, the details of the manner of changing from the existing form should be ascertained. The by-laws, of course, will have to be changed to comply with the new form of organization. It is likely that in most instances the old organization will be dissolved and a new organization formed. If so, a new set of by-laws can readily be adopted.

The questions arising in connection with the transferring of the property from the old association to the new organization are likely to prove perplexing in many cases, especially where the old organization is formed on the capital-stock plan. There are various ways of adjusting this matter, and the best method will depend on the character of the organization and local conditions. A plan which may be followed where the value of each share of stock in the old organization is small and the shares are uniformly distributed among the members is to issue paid-up memberships in the new organization in exchange for the shares in the old and in this way eliminate the capital stock. Thus, if the value of a share in the old organization is \$10 and each member has one share, the membership fee in the new organization can be placed at \$10. If the value of a share in the old organization is \$25 and the annual fee in the new association is placed at \$5, each shareholder may be credited on his annual dues for five years. The difficulty lies in the fact that the shares of stock usually are not uniformly distributed. Thus, one member may have only 1 share and another member have 20 shares. In such a case the method outlined would prove impracticable. Should the membership in the new organization be considerably larger than the old, it may be possible with the receipts from the membership fees of new members to purchase from the old members the extra shares, at their actual cash value, and cancel them.

Where the property holdings are extensive and the capital stock is large, some other method of transferring the property is likely to prove more feasible. In some cases it may be found advisable not to dissolve the old organization, but to let that corporation continue as the owner of the property. The new organization can then lease the property from the old association, paying sufficient rental to provide for depreciation and a fair rate of interest on the investment. If so desired, the old association can be dissolved and the new association can purchase the property, when authorized as necessary for the conduct of its operations, paying for it on the installment plan.

Where two organizations are maintained, one in conformity with section 6 and the other in the form of a capital-stock organization, care should be taken to preserve the bona fide and absolute independence of the two organizations. Otherwise, under such circumstances there is danger that this plan might be held to be a subterfuge.

SECTION 6 ORGANIZATIONS AND STATE INCORPORATION LAWS.

Many of the State laws relating to the incorporation of associations do not provide for the form of organization which is required by section 6 of the Clayton Act. While a large number of States have special laws for the incorporation of cooperative associations, only a few of them provide for the incorporation of cooperative sales agencies without capital stock. It is not unlikely, however, that more of the States will enact appropriate incorporation laws in the near future.¹ It is possible to organize as a voluntary association—that is, without incorporation—but by so doing the organization loses the advantages to be gained from being incorporated.

SECTION 6 AND THE STATE ANTITRUST LAWS.

While section 6 of the Clayton Act confers exemptions upon organizations, which live up to its requirements, from the operation of the United States antitrust laws, it must be kept in mind that that act neither supersedes nor affects the antitrust laws of the various States. The United States antitrust laws deal with interstate and foreign commerce only, while the State laws regulate commerce exclusively within the State. It is essential for everyone contemplating the formation of an association, to secure information in regard to the State laws which have a bearing on the method of organization and operation.

ADOPTING THE BY-LAWS.

When the organization of a cooperative association is taken up, it is well to have several preliminary meetings at which the advisability of organizing and the best form of organization can be discussed. It is advisable to have an organization committee to consider and develop the plan of organization and method of operation suited to the needs of the community. This committee may also be of service in drawing up a set of by-laws for consideration. In this work the committee should avail itself of all the suggestions that can be obtained in regard to the form and contents of the by-laws. It is thought to be indispensable that this committee should have the benefit of competent legal advice in the performance of its duties, in order that there may be no question as to the legality of the con-

¹ Service and Regulatory Announcements No. 20 of the Office of Markets and Rural Organization, U. S. Department of Agriculture, suggests an appropriate State law for the incorporation of section 6 cooperative sales agencies.

templated organization and the methods to be employed in conducting its business. The committee should not forget that the by-laws ought to be a working plan for the organization and therefore should aim to include in them all points of importance. The local conditions are not exactly the same in any two places and therefore such conditions must be considered carefully in drafting the by-laws.

The by-laws prepared by the committee should be considered carefully by the members at a general meeting. At this meeting it is advisable that the by-laws first be read through without interruption or discussion, so that those present may get a general idea of the plan proposed, before taking up the various points in detail. After such reading, the by-laws should be considered very carefully. They should be taken up one section at a time, and ample opportunity should be given for discussion and for making any changes that may be desirable. After each section of an article has been discussed, it is best to vote on the question of adopting that article, before going on to the next. When each article has been considered and passed upon, the matter of voting on the adoption of the by-laws as a whole is merely formal.

The member who acts as chairman at the meeting should be a capable presiding officer in order to expedite matters, as the work of adopting the by-laws may prove long drawn out unless care is taken to see that the discussion is restricted to the vital point then under consideration. If the discussion is allowed to digress too much, not only does a lengthy meeting result, but it is more difficult for the members to keep their minds concentrated on the important points. On the other hand, care must be taken not to create a feeling that the by-laws are being rushed through, without allowing an opportunity for full and free discussion.

CAUTION THAT THE DEPARTMENT'S VIEWS OF LAW ARE NOT CONCLUSIVE.

Effort has been made to draw the accompanying by-laws in such form that they will be suitable for organizations desiring to comply with the provisions of section 6 of the Clayton Act. While effort has been made to shape each provision so that it may be in harmony with law, nevertheless, those who contemplate using the material should be cautioned of the necessity for care on their part also. The antitrust laws are not committed to this department for administration. It has no power to give an authoritative ruling as to their meaning. Indeed, the final interpretation of these statutes rests with the courts. It is suggested that those who desire to make use of these by-laws should act in reference to the matter upon the advice of competent counsel of their own choice.

SUGGESTED FORM OF BY-LAWS FOR A COOPERATIVE NONPROFIT MARKETING ASSOCIATION FORMED WITHOUT CAPITAL STOCK.

The following suggested form of by-laws provides for nonprofit agricultural associations, formed without capital stock. These by-laws should be regarded as merely suggestive and should be changed to meet the individual needs of the association.

The notes following some of the sections are merely explanatory and, of course, are to be omitted in the by-laws adopted by the organization.

BY LAWS OF THE [HERE INSERT NAME OF ASSOCIATION].

ARTICLE I.—NAME.

SECTION 1. This Association shall be known as the [Monroe County Cooperative Fruit Association],¹ and shall be incorporated under the laws of the State of [New York]. Its principal office shall be located in the town of [Hilton, State of New York].

NOTE.—The name should indicate the territory covered and the class of products handled as for instance, the "Maine Potato Shippers' Exchange," "Richmond Egg Circle," etc. Some of the State cooperative laws provide that the word "cooperative" shall form part of the name of organizations incorporated thereunder. Practically all associations should be incorporated under the laws of the State in which they are located.

ARTICLE II.—OBJECTS.

SECTION 1. The objects of this Association shall be to encourage better and more economical methods of production; to secure better results in grading, packing, marketing, and advertising the products of its members; to buy supplies in a cooperative way; to hire, buy, build, own, sell, and control such buildings and other real and personal property as may be needed in the conduct of its operations; to cultivate and develop the cooperative spirit in the community, and to perform any other work which may tend to the betterment of the members and the general benefit of the neighborhood.

NOTE.—Make the objects as definite as possible. It is also well to make them sufficiently broad in scope to cover any future efforts of the association. Care should be taken to state the objects so as to keep the activities within the limits of the power conferred by the statute under which the association is incorporated, as well as in harmony with the articles of association.

ARTICLE III.—MEMBERSHIP.

SECTION 1. Any [bona fide grower of farm products, in any territory tributary to the shipping points of this Association] may become a member of the Association by agreeing to comply with the requirements of these by-laws.

SEC. 2. Upon his entering into such an agreement and paying the membership fee, the Association shall issue a certificate of membership to the applicant. Such certificate of membership shall not be transferable.

SEC. 3. At any time that the Board of Directors determines that a member has ceased to be a bona fide grower of farm products, his membership shall be terminated and his membership certificate shall be canceled.

NOTE.—There may be conditions where it would be wise to limit membership to those who have been recommended by the Board of Directors or who have received a two-thirds vote of the members present at any meeting. In some localities there are persons who are continually finding fault with the way things are managed and such people make undesirable members. Organizations desiring to comply with the requirements of Section 6 of the Clayton amendment of the antitrust laws should be made up entirely of farmers.

¹ All matter appearing in brackets is simply suggestive, and is to be altered to suit the best interests of each individual association.

ARTICLE IV.—FISCAL YEAR, MEETINGS.

SECTION 1. The fiscal year of the Association shall commence [January 1] and end on [the 31st of the following December].

NOTE.—Whenever possible, the fiscal year should end after the close of one season's business and before the opening of the next. Thus, a grain elevator usually has its fiscal year ending in spring or early summer when practically all of the work of handling the previous season's business has been finished.

SEC. 2. The annual meeting of the Association shall be held at the office of the Association, in the town of [Hilton, New York,] on the [second Monday in January] in each year, at [10 o'clock a. m.].

NOTE.—The annual meeting should be held as soon after the end of the fiscal year as will allow for the settlement of all accounts, the auditing of the books, and the preparation of the annual reports of the officers.

SEC. 3. Special meetings may be called at any time by the President. He shall call such meetings whenever [ten] members shall so request in writing.

SEC. 4. Notice of the annual meeting shall be mailed by the Secretary to each member at least [one week] previous to the date of the meeting, and such notice shall be published in a local newspaper not less than [one week] previous to the date of meeting. At least [five] days before the date of any special meeting the Secretary shall mail notice of such meeting to each member, which shall state the nature of the business to be transacted at such meeting.

ARTICLE V.—QUORUM.

SECTION 1. [One-fifth] of the members in good standing shall constitute a quorum for the transaction of business at any meeting.

NOTE.—When the organization is small and compact, the proportion required for a quorum may be larger than in a large organization including considerable territory.

ARTICLE VI.—DIRECTORS AND OFFICERS.

SECTION 1. The Board of Directors of this Association shall consist of [seven] members, who shall be divided into three classes. After the adoption of these by-laws, the members shall elect from among themselves [three] directors of the first class for a term of one year, [two] directors of the second class for a term of two years, and [two] directors of the third class for a term of three years. At the expiration of the terms of the directors so elected their successors shall be elected in like manner for terms of three years. Directors shall hold office until their successors shall have been elected and qualified and shall enter upon the discharge of their duties.

NOTE.—In some States the corporation laws stipulate the number of directors and officers an association shall have. The plan of having each shipping station or district represented on the Board of Directors tends to avoid jealousies between the various districts, and strengthens the confidence of those attempting to cooperate. Some object to having a director hold office for more than one year, believing that the board might be so objectionable to the members that it would be desirable to elect an entirely new board at the annual meeting. However, there are many advantages in keeping some experienced directors on each board. In case the entire board should go contrary to the wishes of the members, the recall of each director could be effected under section 6 of this article.

SEC. 2. The Board of Directors shall meet within [ten] days after the first election, and after each annual election, and shall elect by ballot a President and a Vice President from among themselves, and a Secretary-Treasurer [or a Secretary and a Treasurer] who may or may not be a member of the Association. They shall also choose three auditors from the members, not Directors, officers, agents, or employees of the Association. Such officers and auditors shall hold office for one year or until their successors are duly elected and qualified.

NOTE.—Some organizations desire to have someone outside the membership act as secretary or treasurer, as for instance a local banker. When such an arrangement is desired, it should be provided for in the by-laws.

SEC. 3. Any vacancy in the Board of Directors shall be filled, for the unexpired terms, at any annual meeting, or at any special meeting called for the purpose, in the manner provided for the original election of directors.

SEC. 4. [Four] members of the Board of Directors shall constitute a quorum at any meeting of the Board of Directors.

SEC. 5. [The compensation, if any, of the Board of Directors and the officers shall be determined by the members of the Association at a regular or called meeting of the Association.]

SEC. 6. Any director or officer of the association may, for cause, at any annual meeting or at any special meeting called for the purpose, at which a majority of the members shall be present, be removed from office by vote of not less than two-thirds of the members present. Such director or officer shall be informed in writing of the charges at least [five] days before such meeting and at such meeting shall have an opportunity to be heard in person, by counsel, and by witnesses, in regard thereto.

NOTE.—In some cases, especially when the Board of Directors is large, it is desirable to have an executive committee. Such a committee can be made up of the officers and one or two other members of the Board.

ARTICLE VII.—DUTIES OF THE DIRECTORS.

SECTION 1. The Board of Directors shall manage the business and the affairs of the Association and make the necessary rules and regulations, not inconsistent with law or with these by-laws, for the management of the business and the guidance of the officers, employees, and agents of the Association.

SEC. 2. The Board of Directors may employ and dismiss for cause a Business Manager, and fix his compensation. He shall have charge of the business of the Association under the direction of the Board of Directors.

SEC. 3. The Board of Directors shall require the treasurer and all other officers, agents, and employees charged by the Association with responsibility for the custody of any of its funds or property to give bond with sufficient surety for the faithful performance of their official duties.

SEC. 4. The Board of Directors shall meet on the [first Saturday] of each month at the office of the Association in the town of [Hilton, New York]. Special meetings of the board shall be held upon call of the President or upon written request of [three] members of the board.

ARTICLE VIII.—DUTIES OF THE OFFICERS.

SECTION 1. The President shall—

- (a) Preside over all meetings of the Association and of the Board of Directors.
- (b) Sign as President, with the [Secretary-Treasurer], all checks, notes, deeds, and other instruments on behalf of the Association.
- (c) Call special meetings of the Association and of the Board of Directors.
- (d) Perform all acts and duties usually required of an executive and presiding officer.

SEC. 2. In the absence or disability of the President, the Vice President shall preside and perform the duties of the President.

SEC. 3. The [Secretary-Treasurer] shall—

- (a) Keep a complete record of all meetings of the Association and of the Board of Directors.
- (b) Sign as [Secretary-Treasurer], with the President, all checks, notes, deeds, and other instruments on behalf of the Association.
- (c) Serve all notices required by law and by these by-laws.
- (d) Receive and disburse all funds and be the custodian of all the property of the Association.

- (e) Keep a complete record of all business of the Association and make a full report of all matters and business pertaining to this office to the members at their annual meeting and make all reports required by law.
- (f) Perform such other duties as may be required of him by the Association or the Board of Directors.

NOTE.—When the offices of Secretary and Treasurer are separate, the duties of each should be given in separate sections.

ARTICLE IX.—DUTIES AND POWERS OF THE MANAGER.

SECTION 1. Under the direction of the Board of Directors, the manager shall employ and discharge all employees, agents, and laborers. He shall secure information as to crop and market conditions and furnish the same to the members on request. He shall encourage the production of the best varieties of products demanded by the trade. He shall, as may be required by the Board of Directors, conduct packing schools in order that growers may become trained in the best methods of grading, packing, and labeling their products. He shall have charge of the grading, packing, and inspection of all products handled by the Association and shall have control of the brands and labels and their use on such products, in accordance with the rules of the Association. Subject to the terms of the contracts made by the members with the Association for the marketing of their products, the order of the Board of Directors, and the by-laws and rules of the Association, the manager shall have entire charge of the sale and marketing of such products.

NOTE.—The manager is the most important officer and his power must be limited as little as possible. He can not be held responsible if he is to be dictated to at will by each member or if the officers are to meddle constantly with his work. This does not imply that the manager should be a dictator. He should take the suggestions of the officers and members and from them and his own experience he should construct a business plan. Whenever a manager loses the confidence of the members, he should be replaced with a manager who possesses that confidence. The duties of a manager differ with the different forms of organization and kinds of business. Therefore the duties here outlined must be considered as suggestive. Each association should redraft this provision to suit its purposes. Organizations like creameries and cheese factories may find it advisable to insert an article relating to the duties of the buttermaker or cheesemaker, as in such organizations the duties of the manager usually are more limited.

ARTICLE X.—MEMBERSHIP FEE AND FINANCE.

SECTION 1. Each member shall pay in advance to the Association a membership fee of [\$5] and annual dues of [\$1].

SEC. 2. At the time of uniting with this Association or at any time thereafter, when called upon by the Board of Directors, each member shall loan an amount to be fixed by the Board, not less than [\$10] nor more than [\$100] in cash to the Association to be used in building warehouses or other necessary buildings, and the lease or purchase of lands therefor, or in securing necessary equipment.

SEC. 3. Such loans shall draw interest at the rate of [4] per cent per annum.

SEC. 4. Such loans shall be repaid from a special fund created by levying a percentage assessment on the produce sold and supplies bought through the association, the amount of such percentage to be fixed by the Board of Directors, which amount shall be sufficient to pay [one-fifth] of the entire loan and the interest thereon in each year.

SEC. 5. At the end of each fiscal year each member shall receive a certificate showing the amount of money which he has contributed that year to the special loan fund levied on his produce and supplies. After the original loan has been paid in full, the special assessments shall continue and the holders of such certificates, out of the proceeds arising therefrom, shall be paid the amounts due thereon in the same manner and form as was the original loan, and this process of repayment shall continue during the life of the Association.

NOTE.—This article describes a method suggested for nonstock organizations in securing the necessary capital for the building of warehouses or the purchasing of equipment, inasmuch as no money is secured by the sale of shares of stock. In organizations where only a small outlay for equipment is required, the membership fee can be made sufficiently large to provide the necessary capital.

ARTICLE XI.—EMERGENCY CAPITAL.

SECTION 1. At the time of uniting with the Association, or at any time thereafter, when called upon by the Board of Directors, each member shall deliver to the Association a negotiable, promissory note, payable on demand, to the order of the Association. Such note shall be for the sum of [\$25] and an additional [\$1] for each acre of crops to be grown by the member, the products of which are to be marketed through the Association. But in no case shall this note be for a less sum than [\$35].

SEC. 2. These notes shall be the property of the Association for the purpose of being pledged by the Board of Directors as collateral security for any loan that may be necessary in the conduct of the Association's business. Any member's note may also be available in the settlement of any liquidated damage that may result from the failure of said member to live up to his contract with the Association.

NOTE.—This article is intended to supply capital which is needed only for short periods, as, for instance, during the rush in crop-moving time and other periods when a supply of money is required. Organizations that have a surplus fund for such a purpose may not find it necessary to include this article in their by-laws. If any member knows that the association holds his note, which may be sold to settle any liquidated damage, caused by his breach of contract, it probably will cause him to be more careful about living up to that contract.

ARTICLE XII.—GRADING AND INSPECTING.

SECTION 1. All products grown by the members for sale through the Association shall either be graded and packed on the grower's premises, in accordance with the rules of the association, subject to such inspection as may be established by the Board of Directors, or shall be delivered to the Association, as directed by the manager, in prime condition for grading, packing, and shipping.

SEC. 2. All produce offered for shipment shall be inspected before shipment. If any produce is not in good condition for shipping, such produce shall be sorted, and prepared for shipment at the expense of the owner.

SEC. 3. All brands, labels, and trade-marks established by the Association shall be registered and become its property, and they shall be attached only to such grades as shall be ordered by the Board of Directors.

NOTE.—The rules for grading and inspection will necessarily depend on the organization and the kind of business engaged in, and this should be kept in mind when drawing up the by-laws.

ARTICLE XIII.—CONTRACTS AND AGREEMENTS.

SECTION 1. Every member of this Association shall enter into a contract with the Association in the form required by the Board of Directors, subject to the following provisions:

(a) That the member, by said contract, appoints the [Monroe County Cooperative Fruit Association] his sales agent to sell all products grown by him for sale, or such part thereof as shall be satisfactory to the Board of Directors, as shall be specified in the contract, and binds himself to deliver such products to the [Monroe County Cooperative Fruit Association] for sale at such time and place as the Association directs.

(b) That said contract shall run continuously unless canceled by the member on [March 1] of any year by giving written notice to the Association at least [thirty] days prior to said date that he desires to cancel his contract, subject to any indebtedness due from him to the Association and delivering his copy of the contract to the Association on or before the [first day of March].

NOTE.—No cooperative association should attempt to do business without first having made a definite contract with each member. The manager can not be expected to work to advantage, unless he has definite knowledge of how much of the various kinds of products he is expected to market, and this knowledge should be in his possession early in the season. Unless a member is willing to bind himself under an enforceable contract, he can not expect his association to transact business to his advantage.

ARTICLE XIV.—DUTIES AND RIGHTS OF MEMBERS.

SECTION 1. A member shall have the right to give away or retain for his own use such of his farm products as he may wish, but he shall not sell any product contracted to the Association to an outside party, except products offered to and rejected by the Association.

SEC. 2. In case any member is offered a price in excess of the price then obtainable by the Association, said member shall turn over said offer to the Association for filling from said grower's goods.

NOTE.—This provision is necessary to prevent an outside disgruntled dealer from making a false offer, to test a member's loyalty and arouse dissension, with the idea of disrupting the organization. Allowing the organization to handle this offer compels the mischief-maker to make good on his offer; the grower gets the boosted price, if the dealer does not back down, and the organization handles the deal, and so is strengthened rather than injured. One or two such experiences have usually discouraged this very common form of outside interference.

SEC. 3. Each member shall have a number or mark which shall be permanently stamped on every sack, box, barrel, crate, basket, or other package packed by him or under his direction, for shipment through the Association. Any loss occasioned by improper packing or grading shall be charged to the member whose mark is found on said package.

SEC. 4. Products packed on the grower's premises shall be inspected as they are being packed by an Association inspector. He may be employed and paid by the grower to assist in packing, but he shall be held accountable alone to the Association for his inspection work. His own private mark shall be placed upon each package he packs or inspects and he shall be held jointly responsible with the grower for the pack as it may be disclosed in the final market, ordinary deterioration excepted.

SEC. 5. On or before [April 1] of each year each member shall report to the Association the acreage of products to be grown by him that year and the acreage the products of which he promises to market through the Association. During the growing season, each member shall furnish such information, concerning the crops pledged to the Association, as may be requested by the manager.

NOTE.—This section is intended for organizations handling perishable products such as fruit and vegetables, where it is important to know the volume of business to be handled.

SEC. 6. Each member of the Association shall have only one vote. This shall not be exercised except when all debts and dues owed by him to the Association have been fully paid. Voting by proxy shall not be permitted. Except in case of the removal of a director or officer, as provided in Article VI, section 6, of these by-laws, absent members may vote on specific questions by ballots transmitted to the Secretary of the Association by registered mail, and such ballots shall be counted only in the meeting at the time at which such vote is taken.

NOTE.—In a stock company, which is organized to earn profits on the money invested in the business, a member votes in proportion to the number of shares he holds, but a true cooperative association is based on the individual member, a number of whom unite to do something in which they have a common interest. In the former, money controls; in the latter, men. While there may be cases where the voting power of the members may be made in proportion to the acreage of their products, it will generally be found that any attempt to vary the voting power of members will be unwise. The practice of allowing a member to collect the proxies of absent members and vote the same tends to give a single member powers in the association, which are too dangerous to be allowed.

In some of the largest nonprofit cooperative associations it has been felt that it was neither fair nor wise to demand that the large producing member should be held to the same vote as a small producing member, as their responsibility and liability are so unequal. In such a case the voting power of members may be proportioned according to the amount of their products or acreage handled through the Association.

SEC. 7. Any member may withdraw from the Association at any time between [the first day of January and the first day of the following March]; but such withdrawal

shall not affect any right or lien which the Association has against the retiring member or his property until his indebtedness to the Association is fully paid.

NOTE.—The time of withdrawal should be so fixed as to take effect some time between the close of one season's business and the opening of the next. To permit a member to withdraw during a busy marketing season will result in confusion and may seriously handicap the manager in filling his contracts.

SEC. 8. Any member having a grievance or complaint against the Association may appeal to the Board of Directors [or to the members at any regular or called meeting]. No member shall be suspended or expelled or deprived of the benefits of the Association without having charges preferred against him, reasonable notice thereof having been given and a hearing before the Board of Directors [or by the members at a regular or called meeting].

ARTICLE XV.—INDEBTEDNESS, MEMBERSHIP LIABILITY.

SECTION 1. The amount of indebtedness which may be incurred by or on behalf of this Association shall at no time exceed [\$20,000].

SEC. 2. Each member shall be responsible for his per capita share of all contracts, debts, and engagements of the Association up to and including the maximum indebtedness prescribed in section 1 of this article; but if any member's share of such contracts, debts, and engagements shall prove to be uncollectible, each remaining member shall be responsible, as his additional liability, for such unpaid share or part thereof to an amount equal to such member's original liability. No member shall be liable to the Association for any contract, debt, or engagement arising out of any specific transaction between the Association and any member or members thereof in which he does not participate, unless and until the association shall have exhausted every legal recourse and failed to enforce satisfaction from the member or members participating therein. In all cases any member who, voluntarily or otherwise, contributes to the payment of the debt or obligation of another member or other members shall have an action, several or joint as he may elect, against such defaulting member or members for reimbursement.

NOTE.—Section 2 should be changed to agree with the requirements of the laws under which the organization is incorporated.

ARTICLE XVI.—EXPENSES AND PAYMENTS.

SECTION 1. The expenses of operating the Association shall be met by a percentage charge laid upon returns for produce sold or by a uniform fixed commission per package and by a percentage charge upon supplies purchased, the amount of such charge to be fixed by the Board of Directors.

SEC. 2. Except in cases provided for in Article XIV, section 2, in making sales, all produce of the same grade shall be paid for on the basis of the average price received during such periods as the Board of Directors from time to time may determine. Payments for such produce shall be made to the shippers at the end of each period; in all other cases, payment shall be made to the shippers on the receipt by the Association of the returns for the sale of the produce.

NOTE.—It is important that prices should be averaged on products of the same grade, in order to deal with all members fairly. If prices are not averaged, one man may receive a higher price than his neighbor for shipments of the same quality made on the same day, and this would create dissatisfaction and distrust among the members.

ARTICLE XVII.—COOPERATIVE PURCHASE OF SUPPLIES.

SECTION 1. All merchandise purchased by the Association for any member shall be paid for in cash by the member ordering such supplies at the time of ordering the same, or the proper credit arranged for with some bank, approved by the Board of Directors, at the time of ordering.

NOTE.—Without such a provision an organization purchasing supplies for its members may find that some of the members will refuse to take supplies ordered or else will not pay promptly. A cooperative organization should extend credit to no one, unless it is amply secured.

SEC. 2. In case there are local dealers handling the supplies desired, they shall be given an opportunity to bid on the order before it is placed with an outside agency.

NOTE.—In the cooperative plan of buying farm supplies, the local dealer should be considered. The merchant who in the past has extended credit and rendered other valuable services should be favored when there is cash to be expended. The cooperative committee should go to such local firms and explain that their members are in condition to perform certain services which formerly were rendered by the dealers, and, in view of their less exacting requirements, they expect to save to themselves the price formerly charged for that work.

ARTICLE XVIII.—SAVINGS AND DAMAGES.

SECTION 1. After the season's expenses are paid and a proper sum set aside to cover the depreciation of the Association's property and after provision is made for a contingent fund to be fixed by the Board of Directors, the balance of the season's savings on products sold shall be divided among members and nonmember patrons, if any, in proportion to the amount [or value] of their products sold, and the balance of the season's savings on supplies purchased shall be divided in like manner. In case of a nonmember patron, any part of such sums of money owing him as such, may be applied to the payment of membership fees and dues for him, and, if so applied, when such fees and dues are fully paid a membership certificate shall be issued to him. When any nonmember offers his product and the Association accepts it for sale, such offer and acceptance shall be deemed an application for membership.

SEC. 2. Any member who fails to live up to his agreement, or fails or refuses to deliver to the Association for sale the pledged products, shall pay to the Association, as liquidated damages, the sum of [25 cents] for each [barrel of apples] not delivered by him; said sum may be deducted from any money in the possession of the Association due the member. Any such claim shall be a lien upon the member's loan note.

NOTE.—Some State courts have held that a stipulation for liquidated damage was void in the contract between the member and the Association, because it appeared that it was employed as a mere device to enforce a contract which was made in restraint of trade. These decisions were rendered prior to the passage of the Clayton amendment to the United States antitrust laws. It is now thought that State legislatures may authorize cooperative agricultural associations, which conform to the requirements of section 6 of the Clayton amendment, to embody in their contracts with their members a stipulation for liquidated damages, which will not offend the antitrust laws of the State or of the United States.

Many organizations have failed because members were bound only by a verbal agreement, which is totally inadequate for a stable and enduring organization. The laws of the State should be studied to ascertain whether this clause in the by-laws for holding the members may be legally included.

ARTICLE XIX.—ACCOUNTS AND AUDITING.

SECTION 1. This Association shall install a standard system of accounts, and provide other accounting appurtenances that may be necessary to conduct the business in a safe and orderly manner.

NOTE.—The Bureau of Markets has devised systems of accounts for several lines of cooperative business, such as grain elevators, fruit organizations, creameries, live stock shipping associations, and stores. Information in regard to systems of accounts may be obtained by writing to the Bureau of Markets, United States Department of Agriculture.

SEC. 2. The books and the business of the Association shall be audited [quarterly] by the auditors selected from the membership. A complete annual audit shall be made by a competent accountant previous to the date of each annual meeting, at which meeting his report shall be presented in full. Special audits shall be made upon order of the Board of Directors or upon a majority vote of the members at any regular or called meeting.

SEC. 3. The Association shall endeavor to cooperate with other farmers' cooperative associations in this locality in securing the services of a competent accountant for its annual audit.

NOTE.—While small associations may not feel the need of such a strict system of investigating their accounts, it will pay to have this work done often and most thoroughly. If the Association business is being conducted carelessly, frequent audits will make it known and better methods may be adopted before any great loss occurs. The cost of employing an expert accountant is more than balanced by the confidence which it gives the members and the effectual way in which it stops the criticism of fault finders.

ARTICLE XX.—AMENDMENTS.

SECTION 1. These by-laws may be amended at any meeting by a two-thirds vote of the members present, provided, that notice of such proposed amendment is included in the call for said meeting.

SUGGESTED FORM OF BY-LAWS FOR A COOPERATIVE MARKETING ASSOCIATION FORMED WITH CAPITAL STOCK.

Organizations which are formed with capital stock should replace Articles III, X, XV, and XVIII of the suggested by-laws for organizations without capital stock with the following articles:

ARTICLE III.—MEMBERSHIP.

SECTION 1. Any [bona fide grower of farm products in any territory tributary to the shipping points of this Association] may become a member of the Association by agreeing to comply with the requirements of these by-laws and purchasing at least [one] share of capital stock.

NOTE.—See note following Article III of the by-laws for organizations without capital stock.

ARTICLE X.—CAPITAL STOCK.

SECTION 1. The capital stock of this Association shall be [\$5,000], divided into [500] shares of [\$10] each. No member shall hold more than [10] per cent of the capital stock of the Association.

NOTE.—The amount of capital stock should be large enough to finance the organization adequately. When fixing the share value, the importance of a large membership should not be overlooked and the value should be such that a large number will purchase shares. On the other hand, the share value must not be placed at so low a figure that the organization will not be financed adequately.

SEC. 2. Transfers of shares shall be made upon the books of the Association only when the stockholder is free from indebtedness to the Association.

SEC. 3. A stockholder desiring to dispose of his shares of stock must first offer them to the Association through the Board of Directors, at market value.

NOTE.—This provision, if desired, must be provided for in the Articles of Incorporation to make it legal. To allow outsiders to purchase Association stock may result in the transfer of the control of the organization to those who are opposed to its continuance. If the Association does not purchase stock offered for sale or find a purchaser for it, the owner can not be prevented from selling it to anyone he may choose.

ARTICLE XIII.—CONTRACTS AND AGREEMENTS.

NOTE.—In the case of a capital stock organization or one which is in any sense a profit-making organization, the contract made between it and its member, relating to the sale of his products, should provide in express terms that the member retains the right to fix the price at which his products shall be sold and to sell his products to an outsider at such price as he may determine upon, provided the sale is made through the Association.

ARTICLE XV.—INDEBTEDNESS.

SECTION 1. The amount of indebtedness which may be incurred by or on behalf of this Association shall at no time exceed [\$20,000].

ARTICLE XVIII.—REFUNDS AND DAMAGES.

SECTION 1. After the season's expenses are paid and the proper sum set aside to cover the depreciation of the Association's property, the balance of the season's surplus shall be divided as follows:

(a) The stockholders shall receive not to exceed [6] per cent per annum on the par value of their stock.

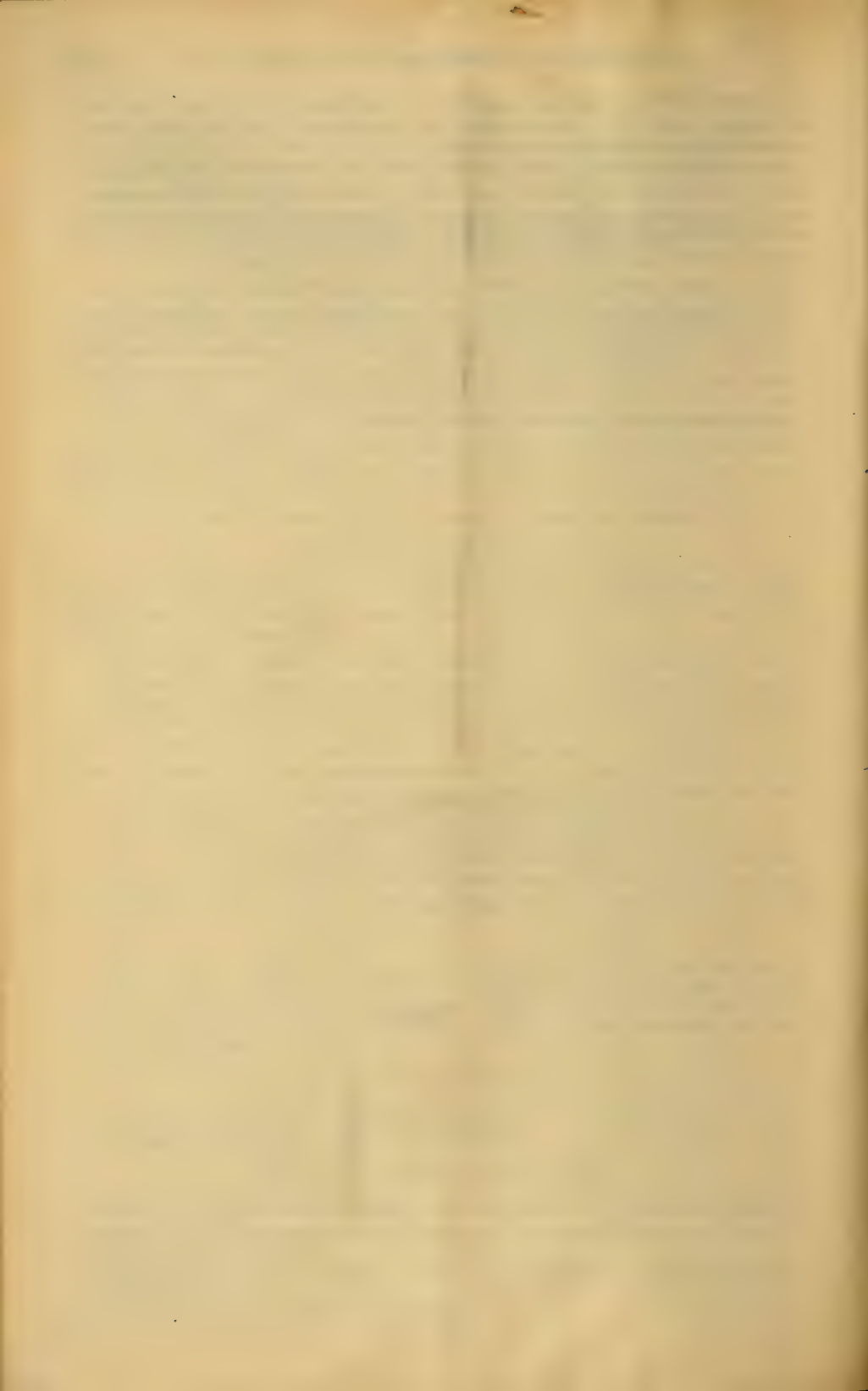
(b) One-half of the balance, if any, shall be set aside as a surplus fund to increase the working capital or to finance future improvements until such fund shall equal at least [25] per cent of the paid-up capital.

(c) The remainder, if any, shall be divided so that the distribution to nonmembers, if any, shall be at one-half the rate paid to members and that part of such remainder derived from sales of products shall be divided in proportion to the amount [or value] of the products of members and nonmembers sold and that part of such remainder derived from purchases of supplies shall be divided in like manner.

SEC. 2. [Same as section 2 for Article XVIII for nonstock organizations.]

NOTE.—Some of the States have laws which provide specifically the manner of apportioning the earnings, and it is therefore important to ascertain the requirements of the law in the State where the association is being incorporated in order that this article may be drawn in conformity therewith. In States where it is permissible to pay patronage dividends to nonmembers, some organizations have adopted the plan of paying patronage dividends to nonmembers at one-half the rate to members and crediting this to the account of the nonmember as payment on a share of stock. When this amount equals the value of a share the nonmember becomes a member.

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THE POLLINATION OF THE MANGO.

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Agricultural Explorer, Office of Foreign Seed and Plant Introduction.

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INTRODUCTION.

In attempting to establish mango culture upon a commercial basis in southern Florida, the Department of Agriculture has introduced during the last 25 years a large number of varieties from India and other important mango-growing regions. In fact, the Tropics have been searched for the best mangos which they produce, and it is probable that the collection now growing in Florida embraces many of the best varieties in cultivation.

The fruiting habits of some of these varieties, however, have not been satisfactory. Several of them fruit very sparsely except in occasional seasons. The Mulgoba, the best variety of all from the standpoint of quality of fruit, has yielded a good crop on an average once in four years. Even at best, some of the varieties seem incapable of producing heavy crops of fruit.

Contrasted with these conditions, most of the common seedling mangos of southern Florida and tropical America are enormously productive and rarely fail to produce a crop.

Numerous explanations have been offered to account for this defect of the choice introduced varieties, but so far as known no investigations have been made with the definite object of determining the precise cause or causes of unfruitfulness and of finding some remedy. A few years ago the trouble was attributed to anthracnose

(*Colletotrichum gloeosporioides* Penzig), a fungus which frequently attacks the young flower spikes and destroys them. Its activities are largely dependent upon weather conditions, being greatest when the air is warm and moist, with frequent showers. This question was studied by McMurran.¹ Sometimes the flowers appear in dry weather and escape unharmed, but a few days of showery weather later on may provide favorable conditions for the development of the fungus, and the young fruits may be destroyed or badly disfigured and deformed. In some seasons trouble from this source is relatively slight, in others serious.

Allowing for injury from this cause, which is an important factor in the production of mangos, it was believed that there must be other factors responsible for many of the crop failures of the Mulgoba and other varieties. Several Indian and West Indian writers have suggested that defective pollination might be one of the most important factors, and it was for the purpose of determining its precise importance that the investigations herein described were undertaken at Miami, Fla., in 1915 and were continued in 1916. In connection with any studies such as this on the pollination of fruit-bearing trees, two papers by M. B. Waite² should be examined.

THE MANGO FLOWER AND ITS POLLINATION.

It has been affirmed by Hartless³ that the mango is largely, if not solely, wind pollinated. Other writers have also advanced the opinion that the wind is an important agent in effecting pollination.

It seems evident, however, that the mango has none of the characteristics of an anemophilous plant, but, on the other hand, presents well-developed adaptations to insect pollination, so that it may be considered truly entomophilous. The amount of pollen which reaches the stigmas was found to be slightly greater in one instance on a very windy day; but this undoubtedly was due to the brushing of one flower against another or against the surrounding foliage, the panicles being thrashed violently about.

Some of the principal characteristics of an anemophilous plant are that (1) the pollen is abundant, compensating for the enormous waste in transport; (2) the pollen grains are dry and incoherent, so that they are easily carried by the wind; and (3) the stigmas are commonly large and bushy and freely exposed, so as to have every chance of catching the floating pollen grains. The mango has none

¹ McMurran, S. M. The anthracnose of the mango in Florida. U. S. Dept. Agr. Bul. 52, 15 p., 4 fig., 4 pl. 1914.

² Waite, M. B. The pollination of pear flowers. U. S. Dept. Agr., Div. Veg. Path. Bul. 5, 110 p., 5 fig., 12 pl. 1894.

——— Pollination of pomaceous fruits. In U. S. Dept. Agr. Yearbook, 1898, p. 167-180, fig. 32-44. 1899.

³ Hartless, A. C. Mango crops and some factors influencing them. In Agr. Jour. India, v. 9, pt. 2, p. 141-159. 1914.

of these characteristics; it produces comparatively few pollen grains, often not more than 200 in an anther, and never more than 1,200 in any that were examined; and it must be remembered that this represents the total number produced by one flower, since there is commonly but one fertile stamen. The pollen grains show a decided tendency to cling together, especially in damp weather; and even on bright, sunny days it was found difficult to dislodge them from the anther by subjecting them to the full draft of an electric fan for 30 minutes, most of the grains still clinging to the anther at the end of that time. The stigma is exceedingly small and not provided with projections of any sort to assist in catching pollen.

On the other hand, the production of honey for the attraction of insects shows a distinct adaptation to insect pollination. The structure of the flower is such as to entitle it, apparently, to be placed in Müller's biological class "A", or "flowers with freely exposed honey."¹ Flowers of this class are visited by insects of several orders, from the short-tongued Coleoptera to the long-tongued Lepidoptera, and members of both these orders, as well as of Diptera and Hymenoptera, have been observed on mango flowers, as will be described later on.

STRUCTURE OF THE FLOWER.

The mango is polygamous and produces its flowers on terminal panicles varying in length from a few inches up to 2 feet, each panicle carrying from 200 or 300 up to more than 4,000 flowers, of which only 2 or 3 per cent are perfect in some instances; in others as many as 60 or 75 per cent. (Pl. I.) The character of the panicle and the number of flowers produced upon it vary with different varieties, as also the length of time they remain in bloom. Some varieties remain in flower but 10 days, others for nearly 2 months, and on one panicle of the Sandersha 4,200 flowers were counted which opened at the rate of 20 to 240 a day, extending over a period of 40 days.

The individual flower² is subsessile, 6 to 8 millimeters in diameter when the corolla is outspread, the calyx composed of five ovate-lanceolate, finely pubescent, concave sepals and the corolla of five elliptic lanceolate to obovate-lanceolate petals, 3 to 4 millimeters long, whitish, with three or four fleshy orange ridges toward the base, and inserted at the base of a fleshy, almost hemispherical disk, obscurely 5-lobed and usually about 2 millimeters in diameter. In the perfect flower the disk is surmounted by a globose-oblique

¹ Müller, Hermann. *Alpenblumen* . . . p. 485. Leipzig, 1881.

Knuth, P. E. O. W. *Handbook of Flower Pollination* . . . v. 1, p. 64. Oxford, 1906.

² The structure and development of the mango flower have been briefly discussed by Burns and Prayag. (Burns, W., and Prayag, S. H. Notes on the inflorescence and flowers of the mango tree. *In* Poona Agr. Col. Mag., March, 1911.)

ovary 1 millimeter broad, with a slender lateral style about 2 millimeters high. To one side and inserted upon the disk is the single fertile stamen, composed of a slender subulate filament about 1.5 millimeters long, surmounted by an oval, purplish red anther 0.5 millimeter long, which dehisces longitudinally. (Pl. II.) Occasionally two such stamens are produced. The whorl is completed by staminodes of varying prominence, short and subulate in some varieties, larger and capitate in others, some even becoming fertile and producing a few pollen grains. In the staminate flower the ovary is wanting.

ANTHESIS AND LIFE OF THE FLOWER.

Anthesis may take place at any time of the day or night, but it seems to be most frequent early in the morning. Usually a large number of buds will be seen to be opening about 6 or 7 o'clock and if the weather is clear the petals will be fully expanded and the anthers dehisced by noon. On exceptionally warm, bright days the anthers sometimes dehisce before the petals are fully expanded. Other flowers may open later in the day, and a few during the night.

The stigma has every appearance of being in a receptive condition immediately after anthesis, and in favorable weather retains its fresh appearance for about two days. At the end of this time the pistil usually commences to turn brown toward the stigmatic end, and the ovary may commence to swell and assume a darker green color. In many flowers, however, the ovary swells but little, the flower drying up and falling off on the third or fourth day.

In flowers which have opened before noon, the pollen usually remains clinging to the anther for several hours, gradually being brushed off by insects or eventually falling. Sometimes much pollen will be left upon the anther until the second day. If the flower is staminate, usually it will shrivel and fall by the third day. Conditions seem to be vastly more favorable for pollination immediately after anthesis than at any later time, because of the larger amount of pollen present. No indications of heteracmy were observed, the stigma appearing to be receptive as soon as the flower opens, usually not more than an hour or two before the anther dehisces. It remains receptive for some time.

POLLINATION.

In spite of the close proximity of anther and stigma, the transfer of pollen from the former to the latter does not seem to be accomplished easily. Both the stamen and the pistil retain an erect position throughout, and the pollen as it is shed usually falls upon the base of the ovary or upon the disk rather than upon the stigma.

The normal method of transferring the pollen from the anther to the stigma must be through the agency of insects. The white,



INFLORESCENCE OF THE BRINDABANI MANGO.

This Indian variety produces larger panicles than many others, the length of the one here shown being about 14 inches. (Photographed by Wilson Popenoe at Miami, Fla., April 7, 1916; P16706FS.)



FLOWERS OF THE WHITE ALFONSO MANGO. SLIGHTLY ENLARGED.

Apex of a panicle, showing the character of the individual flowers, some which show the ovary, style, and stamen indistinctly. In this variety the perfect flowers are the first to open (at least toward the apex of the panicle), and are followed later by many staminate ones. (Photographed by Wilson Popenoe at Miami, Fla., April 7, 1916; P16703FS.)

tumid disk secretes a thick, sweetish fluid which stands out upon its surface in small globules, collecting in larger quantities at the bases of the petals. Insects are attracted to this nectar by the fragrance of the flowers, presumably, and their visits are numerous, especially during the early hours of the day, from daylight until 9 or 10 o'clock a. m. Many insects were observed feeding upon this nectar, and after their visits it was found that there was practically none of it left upon the disk. In moving over the flower in order to get at all sides of the disk, it is almost impossible for an insect of any considerable size to avoid brushing against the anther and dislodging some of the pollen, and in this way transferring the pollen to the stigma, since it is sufficiently rough to cling to the body of the insect and its transport can be effected. It is evident, however, from the comparatively small number of stigmas pollinated that large quantities of pollen are not carried on the bodies of insects, and this belief was confirmed by observation. Examination of insects taken from the flowers has never revealed more than seven or eight pollen grains clinging to their bodies, and not more than one to three or four grains were usually found. The pollen itself is not very abundant, and the number of grains which become attached to the body of each insect visitor is certainly not large.

Of the principal insects observed upon the flowers of the mango in the vicinity of Miami it is necessary to treat in some detail. Those which were captured during the months of March, April, and May, 1915, when most of the mangos were in bloom, and have been identified by the Bureau of Entomology, through the courtesy of Dr. L. O. Howard, Chief, represent the four orders Diptera, Hymenoptera, Lepidoptera, and Coleoptera, ranking about in the order given as to the importance and frequency of their visits. The flies are the only insects which are nearly always present upon mango flowers at any time of day. As they are not so active as some of the Hymenoptera and remain upon a single flower for a longer time, they are scarcely so conspicuous in the early morning as some of the latter, which on sunny mornings can be seen buzzing about the trees in considerable numbers. The commonest fly which was taken on mango flowers was *Ravinia* sp., an insect slightly larger than the common house fly, with a grayish body. Somewhat less common were two species of *Sarcophaga*, with bodies about 1 centimeter in length, the thorax longitudinally striped with black but the general color grayish. A bluebottle fly (*Lucilia caesar* L.) and another bluish green species slightly larger than a house fly, the screw-worm fly (*Cochliomyia macellaria* Fab.), were not common, but a few specimens were taken. Still less common were two very large flies, one a horsefly (*Tabanus americanus* Forst.) which was seen upon the flowers occasionally, and another (*Volucella esuriens* Fab. var.

americana Macq.) a bluish black species with a very broad body about 1.3 centimeters long, which was seen only once or twice.

Among the Hymenoptera one of the most important was the honeybee (*Apis mellifera* L.); yet this insect did not appear to visit the mango with much regularity, being found in considerable numbers at certain times but scarcely coming near the trees on other days, and only observed in certain sections, presumably where apiaries were near by. Perhaps the irregularity of its visits may be due to the fact that it does not find much honey on the mango flower and visits it only when there is a scarcity of other material. The industry with which the honeybee goes from flower to flower, systematically working over the surface of the disk with its proboscis to obtain all the nectar present, at the same time turning its body around in a circle and almost of necessity coming in contact with the anther in its circuit of the disk, makes this insect one of the most effective pollinating agents.

Two other Hymenoptera which visit the mango with great frequency are *Stenodynerus* sp. and *Stenancistrocerus bifurcus* Rob., small wasps with rather slender dark-brown bodies, which in most sections were found more commonly than the honeybee. *Gorytes* sp. is another small wasp somewhat similar in appearance to the last and about as common; *Cerceris* sp. is smaller and was found much less commonly. A somewhat larger wasp, with a particularly prominent head, *Hypocrabro 10-maculatus* Say, and a smaller and lighter colored one, *Tachytes* sp., are two others which were occasionally found. Of the larger wasps, several visited the mango with great frequency, especially during the early morning hours, but it is doubtful whether they are as effective in transferring pollen as the honeybee, the smaller wasps mentioned above, and flies, since their long legs usually keep their bodies at some distance from the essential organs of the flower. A small species, *Arachnophroctonus* sp., is probably the most common one observed and was seen with great regularity, though not in such numbers as several of the smaller wasps. *Palmodes abdominalis* Cress., *Chalybion coeruleum* L., *Polistes crinitus* Fab. var., *P. rubiginosus* Lep., and *Sceliphron cementarium* Dury are others which were taken, but these probably did not have a great deal to do with pollination.

The sole lepidopteran which was collected on mango flowers was the coontie butterfly (*Eumaeus atala* Poey), a species very common in southern Florida and one for which the mango seems to possess considerable attraction. Several dozen specimens were noted on a single tree at one time, and some of them were seen taking up the nectar from the disk with their long probosces. Several of these butterflies were examined to see if pollen could be found clinging to their

bodies, and although a few grains were nearly always present no considerable quantities were ever seen.

While four beetles were taken on mango flowers, one of them with considerable regularity, it is doubtful whether any of the Coleoptera plays an important part in pollination. The common species was *Euphoria sepulcralis* Fab., a grayish black, clumsy insect with a broad body about 1 centimeter long. *Chauliognathus marginatus* Fab., a slender, much smaller, and more active insect, was seen in one locality on several different occasions. *Pachnaeus opalus* Oliv., a pale-green species slightly under 1 centimeter in length, was taken only once, as was also *Chrysobothris chrysoela* Ill., a small black species with six shining red spots on the wing cases. It is doubtful whether either of these has a bearing on pollination.

In spite of the visits of the above-mentioned insects, a large proportion of the stigmas are unpollinated, and it seems probable that very little pollen is transferred from one flower to another, most of the stigmas probably receiving pollen from the anther of the same flower. Examinations were made of numerous flowers to determine the number of pollen grains which had lodged on the stigma. For this purpose those flowers were chosen in which all, or practically all, of the pollen had been shed from the anther, but in which the stigma had not yet commenced to turn brown. Such flowers had every opportunity to be pollinated and where they were found to be unpollinated at that time there was very little chance of their being pollinated at all, since the stigma would have soon been past the receptive stage. An examination of 429 such flowers gave the following results:

	Number.		Number.
Stigmas unpollinated.....	223	On which 4 grains were found.....	26
On which 1 grain was found.....	84	On which 5 grains were found.....	13
On which 2 grains were found.....	47	On which 6 grains were found.....	5
On which 3 grains were found.....	26	On which 7 to 10 grains were found.....	5

The flowers examined were taken from trees in different sections around Miami and under widely differing weather conditions, so that the results probably can be considered a fair average of normal pollination for this region. Differences were noted in the comparative abundance of pollination on different days and different trees, of course, but with one exception these seemed scarcely important enough to warrant notice. After a rather strong wind which blew for about two days, a higher per cent of pollination was found on the Sandersha variety than at any other time. Coupled with this was the presence of large quantities of foreign matter on the pistils, principally fine particles of sand. The flowers had been thrashed about considerably in the wind, and more pollen had reached the stigmas than was normally found in calm weather.

In damp, cloudy weather the pollen grains swell and are much more difficult to dislodge than when the weather is dry and sunny.

After a heavy dew they will be found in this swollen condition, but if not washed off the anther they will be found later in the day, if the sun has come out, to have resumed their normal dry form, oblong-oval.

THE PISTIL.

It has been suggested that some of the unproductive varieties might be found to have abortive pistils and hence to be incapable of being properly fertilized. For this reason the pistils of every available variety were examined. The only difference noticeable among most of them was a slight variation in the width or expansion of the stigma; in some varieties the stigma is not expanded at all, being no wider than the style below it; in a few others it is commonly slightly expanded, and flattened on the upper surface. A V-shaped cleft is frequently visible in the outer edge of the stigma, extending downward in the form of a gradually narrowing groove and finally disappearing. In the freshly opened flower the pistil stands nearly erect, but the stigmatic surface is often slightly to one side and facing away from the center of the flower. Frequently the upper end of the style is curved slightly in this direction, especially when the flower commences to get old.

On one tree only were the pistils found to be commonly abortive; this was a Mulgoba seedling on the Hugh Matheson place at Cocoonut Grove. On this tree many of the pistils were exceedingly short or almost entirely aborted, the rudiments of the style persisting in the form of a short point on the upper surface of the ovary. Some of the pistils seemed to be normal, but a great many were in this abortive state and certainly incapable of being fertilized.

PROTECTION OF POLLEN FROM DEWS AND RAINS.

A frame was erected over one side of a young tree of the Julie variety and a canvas curtain placed over it every afternoon about 4.30 o'clock and removed in the morning soon after sunrise. This curtain was also put over the tree whenever a shower threatened. One-half of the tree was left exposed to the elements as a check. It was thought that by protecting the flowers from rain, so the pollen would not be washed away, there might be a better chance of pollination. By carefully comparing the flowers on the covered and uncovered sides of the tree on days when the weather was fair or showery or there had been a heavy dew the previous night, it became evident that the protection afforded could not be of much practical benefit. The covering did not prevent the access of sufficient moisture to cause the pollen grains to swell and become sticky, and although it prevented the pollen from being entirely washed away by a shower it did not seem to have a great deal of bearing upon the average of pollination. The cover was kept on for several weeks and then

removed entirely. There was no appreciable difference between the covered and the uncovered sides of the tree in the number of fruits produced.

THE POLLEN.

SHAPE AND CHARACTERISTICS OF THE POLLEN GRAIN.

In its normal dry state the pollen of all varieties examined exhibited an oblong-oval form, slightly broader in some varieties and narrower in others, but approximating the same shape in all. When moistened by being placed in water the grains immediately swell and in a very few seconds have become spherical in outline, but on being allowed to dry out they resume their oblong-oval form. Under the microscope the dry pollen grains exhibit one or two sutures extending longitudinally; these disappear when the grain is moistened and swells. The thick outer membrane, or extine, is rugose on the surface and contains four pores, through one of which germination takes place. These pores frequently show very plainly after the pollen grains have been in a culture medium for 24 hours, the intine often protruding slightly from each of them. There are slight differences in the form of the ungerminated pollen grains of different varieties after they have been left for several hours in the culture medium; thus, it was noted that in some varieties the ungerminated grains commonly assumed a distinctly triangular outline, those of another variety were almost spherical, while those of still another were slightly oblate in form.

NUMBER OF POLLEN GRAINS PRODUCED BY THE ANTHERS.

The greatest variation was found in the number of pollen grains produced by the anthers, not only among different varieties but in different anthers from the same tree. The smallest number was found in the anthers of the No. 11 seedlings examined at the Royal Palm Nurseries, Oneco, Fla. The trees were just coming into bloom after rather cold weather, and the flowers did not appear to be strong. The anthers were in many cases rather weakly developed and contained only 35 to 100 pollen grains, 200 being the largest number counted. Later in the season more than 400 grains were counted in anthers from other trees of this same race. The highest number counted was about 1,200, in the anthers of the Mullgoa (not Mulgoba), a variety in which staminate flowers greatly predominate and which produces more pollen than many others. An average number of pollen grains probably could be established for each variety and would be found to vary considerably in different varieties, some averaging not more than 400 or 500, while others certainly would go as high as 700 or 800.

PROPORTION OF PERFECT AND ABORTIVE POLLEN GRAINS.

On examination of the pollen of one variety in January it was found that some of the pollen grains were either small or appeared to be empty. Following up this observation, an attempt was made to determine whether the proportion of poor grains was larger in unproductive varieties than in productive ones and whether this question might have any bearing on the productiveness of a variety.

Early in the season a much larger proportion of poor pollen was found than later on, when the weather was warm and the flowering normal. At the latter time no variety was found in which the number of defective pollen grains would average over 8 or 10 per cent at the highest, and usually it did not average more than 2 to 4 per cent of the total. The number varied greatly in different anthers of the same variety; thus, in the Bennett as much as 25 per cent of empty grains was found in one anther, but this was exceptional and the number of poor grains normally found in this variety was insignificant.

Defective pollen grains are of two kinds: (1) Those which are undersized and (2) those which are empty and appear as irregular, collapsed bodies of a darker color when seen under the microscope. Frequently there is considerable variation in the size of the pollen grains, many being somewhat smaller than normal and a few being very small. The average of every variety, however, shows a very small proportion of grains which are abnormal in appearance, the vast majority being uniform in size and shape, plump, and apparently perfect.

ARTIFICIAL CULTURE OF THE POLLEN GRAINS.

The method used in the artificial culture of the pollen grains was that of Max Pfundt.¹ On a glass slide a small glass ring was mounted; a drop of the culture medium was then placed on a cover glass and this inverted over the ring, the edge of which had been previously greased with vaseline to exclude the air. The bottom of the chamber inclosed by the glass ring was covered with the culture solution in order to keep the vapor tension within the chamber as uniform as possible and to avoid the slightest change in the concentration of the hanging drop. Pollen was sown upon this hanging drop, previous to placing it over the glass ring, by taking a stamen upon which pollen was freely exposed, holding it in the forceps, and lightly touching the surface of the drop in several places. The culture thus prepared was labeled and between observations placed in a large glass moist chamber. Following the method of Pfundt, this moist chamber was kept in the dark.

A considerable amount of experimentation was necessary before a successful culture medium was obtained. Cane-sugar solutions

¹ Pfundt, Max. Der Einfluss der Luftfeuchtigkeit auf die Lebensdauer des Blütenstaubes. In *Jahrb. Wiss. Bot.*, Bd. 47, Heft 1, p. 6-33. 1909.

of densities varying from 1 to 75 per cent were tried, gelatine or leached agar-agar being added to them in varying amounts. Finally, it was found that the best results were obtained with a sugar solution of 25 per cent to which 0.5 per cent of agar-agar had been added. To make this, a 50 per cent solution of cane sugar was prepared and sterilized and then to 10 c. c. of this solution an equal amount of 1 per cent leached agar-agar¹ was added. The sugar solution was made up by weight, one-half ounce of cane sugar being added to 1 ounce of distilled water. Before using the culture medium it was sterilized and after two or three days resterilized, repeating this process two or three times, after which a new solution had to be prepared.

In solutions of a density less than 20 per cent many of the pollen grains burst within a few minutes, as they do in water, and in solutions of a greater density than 30 per cent no germination took place.

The effect of temperature upon the germination of the pollen appeared to be of the greatest importance, and many failures during the early part of the work, when the nights were cold, can probably be attributed to this cause.² Later in the season a few experiments were made to determine the minimum temperature at which germination would take place. Cultures were made as usual, six of one variety, and three of them placed in the ice box, the other three in the moist chamber at room temperature as a check. The result was that no germination took place at 55° F.; at 60° F. there appeared to be a feeble germination of a few grains; at 65° F. the germination was a little better, but still below normal. The best results were obtained between 75° and 80° F., nearer 80° than 75°. No cultures were tried in a temperature above 80° F., which was the highest reached in the moist chamber kept in the laboratory. It seems doubtful whether mango pollen can be expected to germinate normally at a temperature below 60° F.

As to the time required for germination, numerous cultures were examined at the end of 30 minutes, 1 hour, 2 hours, and so on, with the result that at a temperature of 76° F. the first signs of germination were visible within 1 hour. At the end of this time the tubes had not yet reached a length equal to the diameter of the pollen grain, but at the end of 2 hours and 15 minutes the longest pollen tubes were in length almost twice the diameter of the pollen grain. In order to give the pollen tubes time to develop to as great a length as possible, most of the cultures were allowed to remain 12 to 24 hours before examination; at the end of this time development seemed to

¹ This material was obtained from Dr. Albert Mann.

² The failure of McMurran to germinate mango pollen (McMurran, S. M., *The anthracnose of the mango in Florida*, U. S. Dept. Agr. Bul. 52, 15 p., 4 fig., 4 pl., 1914) may have been due to cold weather at the time the attempt was made.

have ceased, as no further changes were produced by leaving the cultures longer. (Fig. 1.)

RESULTS OF GERMINATION TESTS.

By the method described, cultures were made of pollen from all the varieties which it was possible to obtain near Miami, including

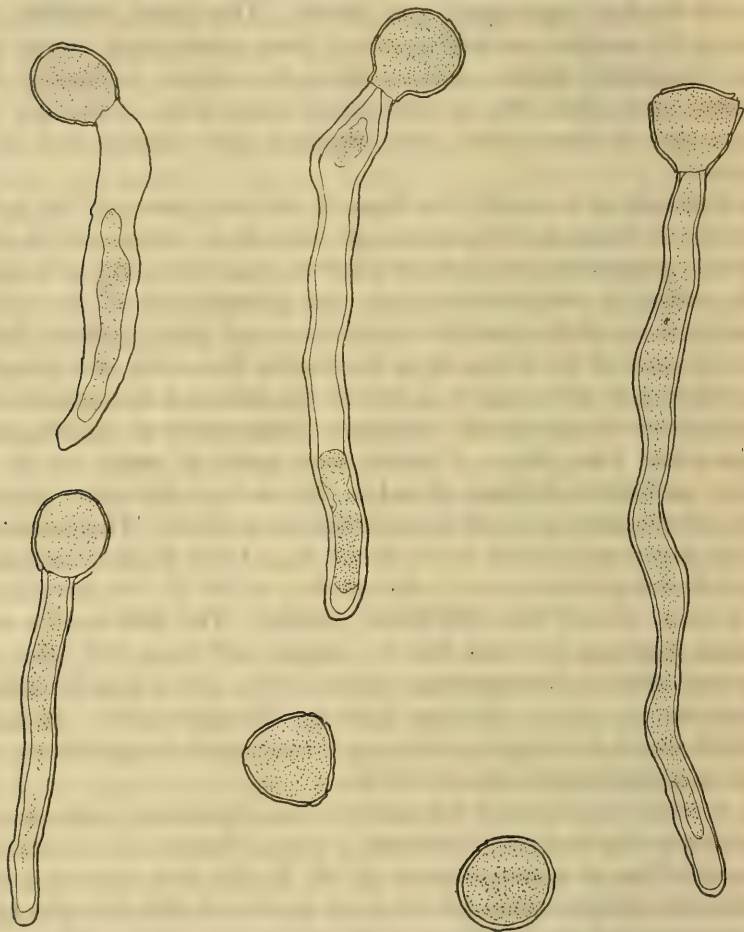


FIG. 1.—Pollen grains of seedling mango of No. 11 type after 24 hours in a 25 per cent sugar solution, showing the development of the tubes. Greatly magnified.

several seedlings. The percentage of germination was in no case high and did not indicate that the superior productiveness of some varieties was due to the greater viability of the pollen. It was significant, in fact, that the best germination was obtained with a variety which is markedly unproductive, the Mullgoa. In the seedling No. 11 race, also, a comparatively good germination was obtained in several instances, while the Mulgoba variety was one of the most

difficult of all to germinate. The percentage of grains which sent out pollen tubes varied from 0 to a little more than 50, but in the vast majority of the cultures would not average above 10 or 15 per cent. No pollen tubes developed to a length exceeding seven times the diameter of the pollen grain, and commonly they did not exceed four or five diameters. Without going into detail regarding the cultures, of which about 300 were made, it can be said that the germination of all varieties was very poor. While the percentage of germination was higher in some varieties than in others, it varied in the same variety upon different days, though the conditions were as nearly similar with regard to culture medium and temperature as it was possible to keep them. The percentage of germination and the vigor of the pollen tubes were greatly inferior to those obtained in cultures of the feijoa (*Feijoa sellowiana*), the lumbang (*Aleurites moluccana*), or several other plants which were tested. It has been pointed out by Prof. E. J. Kraus, however, that pollen germinations made under moist-chamber conditions do not necessarily indicate the germinability of the grains on the stigmas under optimum conditions.

THE PRODUCTION OF FRUIT.

The stigmas, as has been shown, receive no pollen in more than half the instances; and of those cases where they are pollinated, in comparatively few are there more than one or two grains upon each stigma.

Under these conditions it was thought that the production of fruit might be increased noticeably if the stigmas were pollinated more abundantly; with ample pollination, even if some of the pollen grains were defective, a few capable of developing pollen tubes and reaching the ovum should reach each stigma. Working on this theory, a number of hand pollinations were made.

On a 6-year-old tree of the Bennett variety at the E. B. Douglas place, Buena Vista, Fla., five panicles of flowers were selected for hand pollination, and on two days, April 28 and May 1, 1915, pollen from the same tree was applied to all the fresh stigmas on each panicle. The exact number pollinated on each panicle was as follows:

Panicle No. 1.....	30 stigmas.
Panicle No. 2.....	25 stigmas.
Panicle No. 3.....	31 stigmas.
Panicle No. 4.....	25 stigmas.
Panicle No. 5.....	51 stigmas.

These were not all of the perfect flowers on each panicle, but it was thought advisable to pollinate only those stigmas which appeared to be fresh and in a receptive condition at the time the work was done. No fruits were carried on any of these panicles, though on May 21 about 60 well-formed fruits were counted on other panicles

throughout the tree. There were many panicles throughout the tree on which there were no fruits, aside from those which were hand-pollinated.

Other hand pollinations (all with pollen from the same tree) were made in 1915, as follows:

Mullgoa.—Panicle No. 1, all fresh stigmas, pollinated on six successive days.

Panicle No. 2, all fresh stigmas, pollinated on five successive days.

No fruits were carried on either one, although there were a few fruits on other parts of the tree.

Malda.—One panicle, on which all fresh stigmas were pollinated on five successive days, 243 stigmas in all. No fruits set, and there were only two elsewhere on the tree.

Kala Alfonso.—All fresh stigmas on one panicle, hand-pollinated on two successive days. No fruits set, and none elsewhere on the tree. Perhaps the tree was too young; this was its first year of flowering.

White Alfonso.—One panicle, all fresh stigmas, hand-pollinated on three successive days. Set well, agreeing with the other panicles on the tree.

Amini.—One panicle, all fresh stigmas, hand-pollinated on four successive days.

One fruit carried, agreeing with several other panicles naturally pollinated.

Sandersha.—Two panicles hand-pollinated on several successive days. Set several fruits but carried none; behavior differed in no way from many others naturally pollinated.

In general, it may be said that the quantity of fruit produced in all the above cases agreed with the average of other panicles on the tree which were not hand-pollinated. In other words, no appreciable effect was produced by applying an abundance of pollen to the stigmas.

In 1916 this experiment was repeated on a small scale, and in addition an attempt was made to determine whether or not cross-pollination would increase the production of fruit; and an experiment was carried on to determine whether fruits would be produced without the pollination of the stigmas. This latter experiment was suggested by the investigations of Belling¹ who studied young ovaries of the polyembryonic No. 11 race and found that all the embryos appeared to be adventive, no trace being seen of the fertilized egg cell and no traces of pollen tubes being found in the styles. This suggested that fertilization might not be necessary for the development of these polyembryonic mangos.

In order to manipulate the flowers more readily and lessen the danger of contamination, all the lower laterals were removed from the panicles operated upon in 1916, leaving only the flowers upon the upper 4 or 5 inches of the panicle. Working with the whole panicle, which may produce 4,000 flowers, it is next to impossible to insure that no anthers are allowed to dehisce or that some of the stigmas are not accidentally pollinated. The panicles were all inclosed in fine muslin bags stretched over a wire frame attached to the branch below the base of the panicle.

¹ Belling, John. Report of assistant in horticulture. Mango. In Fla. Agr. Exp. Sta. Rpt. [1907]08, p. ex-cxxv, pl. 7-10. [1908.]

A large seedling tree of the No. 11 race, growing on the property of Prof. P. H. Rolfs, at Buena Vista, near Miami, was selected for the principal experiments. On this tree two panicles were bagged, preventing the access of insects, and left to determine whether any fruits would develop without the agency of insects in effecting pollination. The result was that no fruit developed. While the experiment was on a very limited scale, the No. 11 race is exceedingly productive and usually carries a large number of fruits on each panicle, so that a failure to carry any fruits is much more significant than it would be in such a variety as the Mulgoba. This experiment was conducted on several other trees, with the same result in every case.

Two panicles on the same tree were bagged before any of the buds had commenced to open (as in the others), and as rapidly as the flowers appeared the stamens were removed before they had commenced to dehisce. Emasculation was continued until the last flower had opened, and the bags were then left on until ample time had elapsed for the fruits to develop; but all dropped off, indicating that pollination is necessary, even though the egg cell may not develop into an embryo, as appears to be the case from Belling's investigations. This experiment was tried in about 10 other instances, with the same result in each. In a few cases fruits developed parthenocarpically to the length of about 1 inch and then dropped.

Two more panicles on this tree were bagged for hand pollination, and as rapidly as the flowers opened the stigmas were pollinated with pollen from flowers on the same tree. On one panicle 36 stigmas were thus treated, and on the other 30 stigmas. The first panicle carried seven fruits and the second two. This is somewhat more than the average of other panicles on the tree, considering the fact that only a small portion of the panicle was allowed to develop, all the laterals having been removed.

Two more panicles were bagged for cross-pollination and the flowers emasculated as soon as they opened, so that no pollen was liberated within the bag. Pollen of the Sandersha variety from a near-by tree was applied to all fresh stigmas once each day, a total of 83 being pollinated in the first instance and 66 in the second. Seven fruits were carried by the first panicle and six by the second, a considerably larger number than is usually produced by an equal number of flowers on a panicle left to be pollinated naturally. Probably all of these fruits would not be carried to maturity. When last examined, they were one-half to 1 inch long.

Cross-pollination gave equally good results with other varieties. It was tried on the Madras variety, with the result that 8 fruits developed from 58 pollinations, the pollen being taken from a tree of the Cambodiana mango. The Alfonso, when pollinated by this

same variety, set 6 fruits from 47 pollinations. The Sandersha, pollinated by the same variety, set 10 fruits from 52 pollinations. The Paheri, pollinated by the same variety, set 2 fruits from 59 pollinations. Pollinated by the Sandersha, the Paheri set 17 fruits from 92 pollinations.

Though the best results were obtained from cross-pollination, nothing has been found to indicate that any of the varieties are self-sterile. Both the experiments in self-fertilization and the behavior of many isolated mango trees in southern Florida and elsewhere indicate that the mango is normally self-fertile.

From the fact that pollination ordinarily is scanty, it might be concluded that productiveness could be increased by insuring more abundant pollination. While this is perhaps true, a careful consideration shows this point to be of comparatively little practical importance. The total number of flowers produced is so enormous that it is usually of small consequence if half of the perfect ones fail altogether to receive pollen (Pls. III and IV). In practically all of the seedling mangos it has been observed that the trees often set many more fruits than they can carry to maturity, and this has been noted with the Bennett, Cambodiana, Haden, and other budded varieties as well. Possibly it might be of importance in the case of varieties producing a very small number of perfect flowers, such as the Mullgoa and the Jamshedi, but in the varieties which are being planted commercially in Florida the percentage of perfect flowers is satisfactorily large.

FLOWERING HABITS OF THE MANGO.

Different races and varieties of the mango exhibit well-defined characteristics of flowering, both with regard to flowering under adverse climatic conditions and with regard to the abundance of flowers produced and the length of time the tree remains in bloom. There are also marked differences in the proportion of perfect to staminate flowers in different varieties and in the distribution of the perfect flowers upon the panicle.

REGULARITY OF FLOWERING.

There can be no doubt that the production of flowers is strongly influenced by the soil moisture during the normal blooming season. This fact has not only been noted by various observers in Florida, but has been recorded elsewhere. In some sections where the ground is low and continually moist, the mango rarely flowers, while in regions where there is a well-defined dry season corresponding to the normal flowering season, allowing the soil to dry out thoroughly, flowers are produced abundantly. From the behavior of the numerous varieties and seedlings in the vicinity of Miami, it is apparent



YOUNG FRUITS ON ONE PANICLE OF A PHILIPPINE SEEDLING MANGO.

The seedling race of mangos known as the Philippine, or Filipino, is grown in Cuba and Florida and sometimes produces heavy crops, with many fruits to the panicle. The panicle here shown was pollinated naturally and shows the profusion of fruits which often develop. Many of these will drop, not more than four or five usually being matured. (Photograph taken by Wilson Popenoe at Herradura, Cuba, February 20, 1916; F16665FS.)



PARTLY GROWN FRUITS ON A SEEDLING MANGO OF THE PHILIPPINE RACE.

A later stage than that shown in Plate III, many of the young fruits having dropped. The process of thinning will be carried farther, probably not more than four or five fruits eventually maturing on this panicle. (Photographed by Wilson Popenoe at Herradura, Cuba, February 20, 1916; P16666FS.)

that some are affected less injuriously by a wet soil than others. Most notable among those which flower under conditions somewhat unfavorable may be mentioned the Sandersha and the Julie of the grafted varieties and the No. 11 race among the seedlings. During the early spring of 1915, when the weather was unusually wet and the ground was scarcely allowed to dry out, all these came into bloom, while the Mulgoba and numerous other varieties failed to show any signs of bloom until the rains had ceased for a time and the wet spell had been followed by two weeks of dry, sunny weather. It is evident that in many varieties some check to vegetative growth, such as is given by a thorough drying of the soil, is necessary to encourage flowering. While conclusive evidence is lacking, it seems probable that fruit buds are not formed in the mango a long time in advance of the flowering season. This is in contrast to many temperate fruits, such as the apple, in which the fruit buds are formed during the summer, lie dormant over winter, and appear as flowers in the spring. In the mango no indication of tissue differentiation to form fruit buds has been observed in the vegetative cones of the young branchlets until a very few weeks previous to the appearance externally of the young panicle. Thorough drying of the soil a few weeks before the normal flowering season, therefore, should be efficacious in encouraging the formation of fruit buds, and in practice this has proved many times to be the case.

The necessary check to growth sometimes is produced artificially in the Tropics by root pruning, hacking the trunk, or other means. It seems highly desirable, however, that the check be produced normally through the drying of the soil, and hence the best mango regions probably will remain those where the normal flowering season occurs at a time of year when the weather is usually dry. It is significant, however, that some varieties seem to require this check to a less degree than others, and this may make possible the cultivation of choice varieties which will be much more regular in fruiting than the Mulgoba when grown under slightly adverse conditions.

LENGTH OF FLOWERING PERIOD.

In addition to flowering regularly, even when climatic conditions are somewhat unfavorable, another characteristic is important in connection with flowering, i. e., the length of time during which a tree remains in bloom. This varies greatly in different varieties. Some will develop all their flowers within 10 days from the opening of the first buds; other varieties, such as the Sandersha and the Julie, keep on developing new panicles of flowers throughout several weeks, or even months, and in 1915 there was not a single day between the middle of January and the latter part of May on which flowers could

not be found on the Sandersha tree in the Plant Introduction Garden at Miami. This characteristic is of importance, in that it gives the tree a greater opportunity to set fruit; often the attacks of the anthracnose fungus are most severe when a tree is in bloom, and the entire crop of flowers is destroyed. In some varieties this means a crop failure, since the tree will not produce any more flowers during the season; but in the Sandersha (if early in the season) it would merely mean that the flowers which happened to be present at the time the fungus attack occurred would be lost and the flowers which appeared later might happen to strike more favorable weather, when the ravages of the fungus were less severe, and a crop of fruit result. Many of the seedling races possess the ability to flower a second time if one crop is destroyed by fungi. In fact, H. A. Van Hermann states that he has seen seedlings in Cuba flower four times during the winter and early spring months before they succeeded in setting a crop of fruit. The first three crops of flowers, coming at a time when the weather encouraged the growth of fungi, were lost and the tree was forced to bloom again. In case the first crop of flowers results in a good setting of fruit there is no further production of flowers during the season, according to Van Hermann.

PROFUSION OF BLOOM.

Sometimes the entire tree comes into bloom at one time, covering itself with flowers; again, one side of the tree may flower, while the rest of the tree shows no buds, or the flowering may be confined to a small section of the tree, which probably represents the branchlets arising from one main limb. This corresponds to the habit of growth exhibited by the mango, which is noted but not explained by Schimper.¹ Frequently the young branchlets over a small portion of the tree will come in flush while the rest of the tree is dormant. It was noticed during the season of 1915 that a number of Mulgoba trees produced flowers over only a small proportion of their surfaces. It might be expected that the remainder of the tree would flower at another time, but this is by no means always the case.

PROPORTION OF PERFECT TO STAMINATE FLOWERS.

It is true that some varieties which bear heavy crops are characterized by a large percentage of perfect flowers, while others which are known to be unusually regular in fruiting, although they may not produce such heavy crops, are characterized by a rather low percentage of perfect flowers.

The Philippine race, which sometimes produces enormous crops, with several fruits in each cluster, often has more perfect than staminate flowers. The No. 11 race, which also produces heavy

¹ Schimper, A. F. W. *Plant Geography upon a Physiological Basis* . . . 839 p. Oxford, 1903.

crops, with several fruits arising from a panicle, has a high percentage of perfect flowers. Most of the Indian varieties, which commonly mature but one fruit from a panicle of flowers, usually have a lower percentage of perfect flowers than either the No. 11 or the Philippine race of seedlings. The Haden, however, has a large percentage of perfect flowers and retains the bearing habit of the Indian varieties, though occasionally it matures more than one fruit on a panicle. The Julie, which has a very high percentage of perfect flowers, commonly matures but one fruit on a panicle. It seems very doubtful whether there is any correlation between the percentage of perfect flowers and productiveness.

In some varieties, at least, the perfect flowers do not open continuously during the time the panicle is in flower, but most of them appear within a limited period of time. This is illustrated by a count made of one panicle of Sandersha flowers, showing the number of perfect and staminate flowers which opened each day. (Table I.)

TABLE I.—Count of one panicle of flowers of the Sandersha mango, showing period of opening.

Date.	Time of day.	Flowers.			Date.	Time of day.	Flowers.		
		Perfect.	Staminate.	Total.			Perfect.	Staminate.	Total.
March:					April:				
30.....	4.00 p.m.	0	19	19	16.....	1.00 p.m.	2	142	144
31.....	3.30 p.m.	0	21	21	17.....	10.30 a.m.	1	105	106
April:					18.....	11.00 a.m.	1	119	120
1.....	3.15 p.m.	0	38	38	19.....	2.00 p.m.	0	127	127
3.....	7.00 a.m.	0	70	70	20.....	1.00 p.m.	0	132	132
4.....	1.30 p.m.	0	40	40	21.....	1.00 p.m.	2	106	108
5.....	2.30 p.m.	0	37	37	22.....	2.00 p.m.	2	95	97
6.....	3.15 p.m.	0	90	90	23.....	1.00 p.m.	3	100	103
7.....	1.00 p.m.	0	92	92	25.....	8.30 a.m.	151	115	266
8.....	1.30 p.m.	0	104	104	27.....	10.00 a.m.	152	96	248
9.....	12.30 p.m.	1	126	127	29.....	12.00 m.	104	84	188
10.....	3.15 p.m.	0	178	178	May:				
11.....	12.00 m.	0	200	200	1.....	3.00 p.m.	118	116	234
12.....	1.30 p.m.	0	230	230	3.....	3.00 p.m.	30	186	216
13.....	12.30 p.m.	1	202	203	5.....	11.30 a.m.	9	158	167
14.....	1.30 p.m.	3	237	240	7.....	1.30 p.m.	0	82	82
15.....	2.00 p.m.	2	185	187	10.....	10.00 a.m.	0	8	8

These figures give a total of 582 perfect flowers and 3,640 staminate, or a grand total of 4,222.

DISTRIBUTION OF PERFECT FLOWERS ON THE PANICLE.

When only a small number of perfect flowers are produced, as in such varieties as the Mullgoa, Kistapal, and Salamar, in which 5 to 50 have been counted on one panicle, these flowers usually are produced upon the apex of the main axis of the panicle, with often a few upon the uppermost lateral branches. As the proportion of perfect flowers increases they are found farther down upon the panicle, and in many varieties they occur even upon the lowest lateral branches,

though it is very common for the lower laterals to produce nothing but staminate flowers and the perfect flowers to be limited to the laterals on the upper half of the panicle.

SUMMARY.

Attacking the problem of mango sterility from several angles, as herein outlined, it has been possible to eliminate several factors heretofore generally believed to have some bearing on the question. Apparently the difficulty is not due to any morphological defect in the pollen or to defects in the mechanism of pollination. By the exclusion of these factors and from the observation of trees in Florida and other regions during several seasons, the conclusion has been reached that the problem is a physiological one, connected with nutritional conditions as influenced by changes in soil moisture and food supply, principally the former. While such factors as lack of pollinating insects and loss of pollen through excessive rains may at times have an injurious effect upon the mango crop, it seems safe to assert that the question of pollination is of comparatively little importance from a practical standpoint. Experiments have been undertaken, with the cooperation of Prof. E. J. Kraus, to test the practicability of inducing the formation of flower buds through ringing, girdling, and banding the limbs with wire. The work of Prof. Kraus at the Oregon Agricultural Experiment Station¹ with pomaceous fruits has suggested various methods of this nature, and the results of these experiments with the mango will be watched with interest. At various times excellent results have been reported from ringing and girdling the mango, but systematically arranged experiments along this line have not been undertaken. It may be that ringing the mango should become a standard orchard practice, but it is hoped that from the present experiments it will be possible to learn more concerning the physiology of fruit setting in the mango and thereby establish other orchard practices, such as cultivation or pruning, best adapted to insure commercial crops of fruit. In Cuban experiments, fertilizers very rich in potash have yielded good results in the way of increased fruit production. It is to be hoped that such experiments as these will bring to light a practicable method of encouraging the formation of fruit buds on soils or under climatic conditions which normally tend to produce vegetative growth to the exclusion of reproduction.

¹ Kraus, E. J. The study of fruit-buds. *In* Oreg. Agr. Exp. Sta. Bul. 130, p. 12-21, fig. 15-23. 1915.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 543

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

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CONTROL OF PEACH BACTERIAL SPOT IN SOUTHERN ORCHARDS.

By JOHN W. ROBERTS, *Pathologist, Fruit-Disease Investigations.*

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INTRODUCTION.

In most of the peach-growing sections of the eastern half of the United States the disease commonly called bacterial spot, or bacteriosis, is becoming increasingly important, especially in the more southerly sections. It is impossible to give any estimate of the damage which it causes annually, (1) because it is mainly a disease of the foliage and (2) because of its great seasonal variation. It has been reported as occurring in practically the whole of the eastern United States, including Massachusetts, Connecticut, New Jersey, Delaware, Maryland, Pennsylvania, Michigan, Illinois, Indiana, Ohio, Kentucky, Tennessee, Virginia, North Carolina, South Carolina, Georgia, Alabama, Arkansas, Missouri, Nebraska, and Texas. As a rule, it is most serious in the more southerly peach-growing sections, but during recent years many specimens from farther north were sent to the Bureau of Plant Industry for identification and for suggestions as to control measures. During the years 1914 and 1915 the writer found the disease to be serious in the Ozark region of Arkansas, being surpassed in destructiveness only by scab and brown-rot.

NOTE.—This bulletin is of interest to peach growers in the eastern half of the United States and particularly those of the more southerly parts of this section. It is also of interest to plant pathologists.

DESCRIPTION OF THE DISEASE.

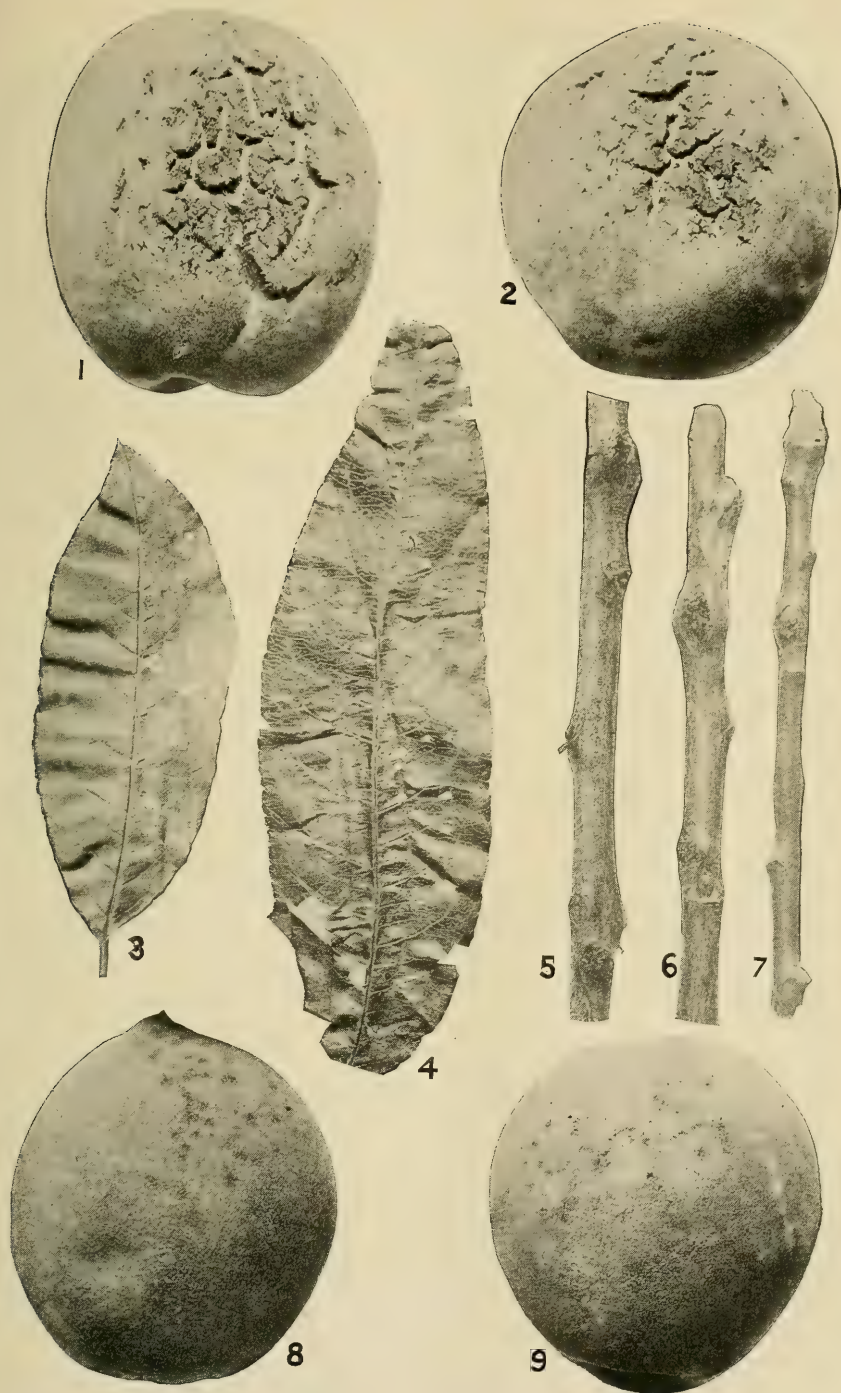
Leaves, fruit, and twigs are affected, but the injury to the leaves usually is the most serious phase of the disease.

The first indication of injury to the foliage is the appearance of small, nearly transparent, water-soaked areas. These are particularly noticeable when a leaf is held between the observer's eyes and the sun. Later, the spots enlarge, turn darker, and at length become dry and brittle. Then, as a final stage, they crack away from the living tissues and often fall out entirely, giving the leaf the so-called shot-hole appearance (Pl. I, figs. 3 and 4). Sometimes a number of spots, especially those near the margin of the leaf, will coalesce, giving the leaf a burned or blighted appearance. Later, these dead areas, composed of several spots which have run together, may break away and fall to the ground, giving the leaf a peculiar, ragged appearance. Infections may be so numerous as to injure every leaf on the tree, they may be localized so as to affect seriously only the foliage of certain limbs, or the infection may be mild all over the tree, so mild at times as not to be especially important.

Though the disease in its later stages on the leaves is difficult to distinguish from spray injury, damage by shot-hole fungi, and some other diseases, when it appears on the fruit, especially after it has passed the first stage of its development, it is not easily so confused. Minute spots, scarcely darker than the skin of the young fruit, denote the first appearance of the disease. These spots soon become somewhat enlarged and gradually become darker in color. Later, as the fruit enlarges, small cracks appear in the diseased areas (Pl. I, figs. 8 and 9). Beginning with this stage, the disease is most characteristic and is not easily confused with any other type of injury. Later, with further growth of the fruit, the cracks are extended, and finally several may run together, making long irregular fissures (Pl. I, figs. 1 and 2). The flesh of the fruit is protected by the formation of a corky layer in these cracks, but nevertheless the fruit itself presents a ragged and irregularly cracked surface which, except in mild cases, renders it unfit for market.

A grayish water-soaked spot is the first indication of the disease on the twigs of the current season. This soon becomes dark and later is sunken. If there are a number of infections close together they may coalesce, forming a rather large canker, which may persist, with rather abundant flow of gum. Plate I, figures 5, 6, and 7, shows advanced stages of the disease on twigs.

Usually in the Ozarks the first infections on leaves, twigs, and fruit occur in May, or sometimes even earlier. The disease does not become conspicuous, however, until much later; in the Ozarks about the middle of June in the case of leaves and twigs and about



FRUIT, LEAVES, AND TWIGS OF ELBERTA PEACHES, SHOWING VARIOUS STAGES OF PEACH BACTERIAL SPOT.

1 and 2, Advanced stage of the disease on fruits that are nearly ripe; 3 and 4, leaves showing late stages of the disease; 5, 6, and 7, bacterial cankers on twigs; 8 and 9, fruits showing earlier stages of the disease than are shown in figures 1 and 2.

July 15 in the case of the fruit. At these times the leaves are beginning to become ragged and shot holed and the affected fruits are showing conspicuous cracks.

As far as the peach is concerned, the direct killing of twigs and branches is rare, and this phase of the disease is not in itself to be considered as very serious. The twig lesions are of importance, however, in that it is in these that the causal organism passes the winter. Orchards in which direct damage to the fruit causes much loss are also rather rare. It is the injury to the leaves, sometimes amounting to complete defoliation and often to 25 to 50 per cent defoliation, and the consequent damage to tree and fruit through the curtailment of the supply of plant food, which make this an important disease.

CAUSE OF THE DISEASE.

The disease is of bacterial origin and is caused by *Bacterium pruni* Erw. F. Smith.¹

Smith² in 1908 first successfully inoculated the foliage of the peach with the organism which he had obtained in pure cultures from the plum.

Rorer³ in 1909 reported successful inoculations on peach leaves with pure cultures of the organism from the same source. He also obtained the organism from twigs and described the disease on the fruit.

Many successful cross inoculations were reported upon by Rolfs⁴ in 1915, confirming the work of Smith and Rorer and establishing beyond doubt that the disease on foliage, fruit, and twigs is caused by the same organism.

Bacterium pruni is described as a short rod, occurring singly, in pairs, or sometimes in chains, motile by polar flagella, from 0.001 mm. to 0.0018 mm. long and about half as wide. Warm, moist weather conditions, with the trees in a weakened state, due to previous injury by freezing, lack of pruning, lack of fertilization, etc., are most favorable for infection and subsequent growth of the causal organism.

VARIETAL SUSCEPTIBILITY.

Practically all varieties are attacked, at least to some extent, by this disease. The Elberta, the leading commercial peach, is very susceptible. It is very difficult to estimate the relative suscepti-

¹ Smith, Erwin F. Observations on a hitherto unreported bacterial disease, the cause of which enters the plant through ordinary stomata. *In Science*, n. s., v. 17, no. 429, p. 456-457. 1903.

² Smith, Erwin F. Occurrence of *Bacterium pruni* in peach foliage. *In Science*, n. s., v. 30, no. 763, p. 224. 1909. Abstract of paper read at the meeting of the Society of American Bacteriologists, December, 1908.

³ Rorer, J. B. A bacterial disease of the peach. *In Mycologia*, v. 1, no. 1, p. 23-27. 1909.

⁴ Rolfs, F. M. A bacterial disease of stone fruits. N. Y. (Cornell) Agr. Exp. Sta. Mem. 8, p. 381-436, fig. 59-70. 1915. Literature cited, p. 435-436.

bility of different varieties, but the Bilyeu, Elberta, Carman, Champion, Oldmixon, Sneed, and Waddell appear to be more susceptible than such varieties as the Hiley, Belle, Fox, Edgemont, Rivers, Early Crawford, and Salway. Rolfs¹ gives an extensive list of varieties, with estimates as to relative susceptibility and resistance. All varieties were found by him to be susceptible to some extent.

CONTROL EXPERIMENTS.

It was not until 1913 that the problem of control came directly before the Bureau of Plant Industry. During that year one section of an orchard in the Ozark region of Arkansas in which spraying experiments for the control of brown-rot and scab were being conducted suffered severely from an attack of this disease. Twigs, leaves, and fruit were badly infected, and no control by the spraying was apparent. It may be said both from the experiments of this bureau and from those of Rolfs¹ that the sulphur mixtures (not lime-sulphur solution), which are the only known fungicides that can be used with safety on the peach during the growing season, will not control this disease. In Georgia in 1909 the writer noticed that trees which were in good growing condition, that is, which had been well pruned, fertilized, and cultivated, were practically free from the disease, whereas those which had been allowed to go without pruning, fertilization, and cultivation were to a considerable extent damaged by the disease. Similar observations were made in Georgia in 1912, but the disease did not then appear to be of sufficient importance to demand experiments in control.

When, therefore, in 1913 it seemed desirable to work out proper means of control, the first things that suggested themselves were naturally pruning, fertilization, and cultivation. The writer's observations were further supported by a statement in the report of the Director of the Missouri Agricultural Experiment Station for 1912² to the effect that in the case of winter-injured trees the plats fertilized with nitrogen were nearly free from the bacterial disease, while in adjacent unfertilized plats the damage was very great.

During the seasons of 1914 and 1915 the same orchard in which the spraying experiments had been conducted in 1913 was used for experimental work in the control of bacterial spot. This orchard consisted of a block of Elberta trees which was bounded on one side by a road, on the second side by a cultivated field, on the third side by a meadow, and on the fourth side by an apple orchard. The disease had been particularly severe in the corner adjacent to the meadow and the apple orchard. Accordingly, the experiments were con-

¹ Op. cit.

² Munford, F. B. Fertilizing peach trees. *In* Mo. Agr. Exp. Sta. Bul. 111 (Rpt. [1911]12), p. 247-248, 1913.

ducted in that section of the orchard. The trees themselves had been well pruned and were of good average size. The soil was, in texture, good peach soil, but inclined to be somewhat lacking in natural fertility.

In 1914 treatment was as follows: Plat 1, consisting of 18 trees, received 2 pounds of nitrate of soda per tree; plat 2, consisting of 6 trees, received 1 pound of nitrate of soda per tree; plat 3, consisting of 12 trees, received 3 pounds of nitrate of soda per tree; plat 4, consisting of 18 trees, received 3 pounds of bone meal per tree; plat 5, consisting of 12 trees, received 6 pounds of bone meal per tree; and plat 6, consisting of 12 trees, received 4 pounds of acid phosphate per tree. The fertilizer was applied on May 4 in a ring or band about the trees, directly below the ends of the branches. The application of fertilizer was immediately followed by cultivation.

On June 8 the disease was evident, though not as yet serious, in all the plats, including both treated and untreated trees. The amount of infection in all plats appeared to be about equal. Each plat had some trees which were next to the meadow, the grass of which extended nearly to the trunks of the trees. In all cases these trees, deprived by the meadow of their proper share of food materials and moisture, were the worst affected. By July 2 plats 1, 2, and 3 (the nitrate plats) showed few leaf infections except in the case of the trees close to the meadow. Even these, however, were much freer from the disease than were the untreated trees. The leaves of the unfertilized trees showed considerable injury, about 20 per cent of them being affected. Plats 4, 5, and 6 (the bone-meal and acid-phosphate plats) appeared to be somewhat better than the untreated portion of the orchard, but the difference was not nearly so striking as the difference between the nitrate-of-soda plats and the untreated trees.

By the end of the season the untreated trees had lost fully one-third of their leaves. Of the remaining leaves, about 30 per cent showed some injury from the disease. On the nitrate-of-soda plats there was little defoliation from the disease, and few leaves showed any infection. Most of the injury was on the trees next to the meadow. The leaves of the trees in these plats were large and possessed the dark-green color characteristic of healthy peach leaves, which is the usual effect of fertilizing peach trees with nitrate of soda. Plats 4, 5, and 6 (the bone-meal and acid-phosphate plats) were in somewhat better condition than the untreated plats, but not especially so. It will be noted that, while at the beginning of the season injury from the disease was slight and about the same in all the plats, it later increased and became commercially important only on those plats which had not received the nitrate-of-soda treatment.

During 1914 there was no fruit on any of the trees in this orchard, the fruit buds in the peach orchards of northwestern Arkansas having been killed by low temperatures in January.

The experiments of 1915 were conducted in the same orchard as were those of 1914. Plat 1, consisting of 34 trees, was treated with nitrate of soda at the rate of 2 pounds per tree; plat 2, consisting of 24 trees, was treated with nitrate of soda and dried blood at the rate of $1\frac{1}{2}$ pounds of the former and 1 pound of the latter per tree. Six trees between these two plats were left untreated and were considered as checks, as was also the remainder of the orchard.

Owing to the press of other work, the fertilizers were not applied until May 22. The orchard had been cultivated a week before and was again cultivated on June 1. The trees had bloomed on April 25 and had set a good crop.

On June 10 there was very little of the disease on the nitrate plats, but considerable was beginning to show on the untreated plats. The large dark-green leaves of the nitrate plats were in sharp contrast to the relatively pale leaves of the unfertilized plats. By June 30 the contrast was much greater, as the disease had given a ragged appearance to the foliage of the untreated plats, while the nitrate plats remained nearly free from infection.

On August 5 the fruit was just beginning to ripen. On certain limbs of the untreated trees there was considerable injury to the fruit, though not enough to be of importance commercially. The fruit of one limb, for instance, would be badly affected, while that of the remainder of the tree would be free from injury. There was almost no injury to the fruit of the nitrate plats.

By the end of the season the difference in the appearance of the foliage of the nitrate plats and the untreated ones was as great as during the previous season. The difference between this damage and the total damage caused by the bacterium was about the same on both the fertilized and unfertilized trees as during the previous season. There was no perceptible difference between plats 1 and 2 in so far as the amount of infection was concerned. Eight of the fertilized trees which bordered on the meadow were considerably more affected than the others in the same plats, but were infected much less than the unfertilized trees.

During both years the nitrate plats included the trees which during 1913 suffered the heaviest infection. Sixteen of the trees treated with nitrate of soda in 1914 were included in the nitrate plats in 1915. These, however, showed no superiority, in so far as resistance to the disease was concerned, over those which had not received fertilizer during the previous year. In the experimental plats of both 1914 and 1915 the sole difference in the treatment of the plats, including the check plats, was one of fertilization. All had been given the

same amount of pruning and cultivation and received throughout the two years exactly the same treatment except as to the fertilization outlined in these experiments. It is evident, therefore, that the striking differences noted were due to the nitrate of soda alone. The larger amount of infection on the trees of all plats growing next to the meadow, upon which the grass was encroaching, indicates that cultivation was generally beneficial to all the plats. Rolfs,¹ in Missouri, obtained good results in the control of this disease by means of cultivation, pruning, and the use of nitrogenous fertilizers. In those regions of the South in which the disease has been serious, nitrogen appears to be the most deficient of the important plant-food materials.²

These experiments indicate that, at least in the South, peach orchards which are kept in good growing condition are not liable to suffer from the disease to any serious extent. Proper pruning, cultivation, and fertilization so increase the resistance of the trees that the causal organism is unable to attack them successfully.

Pruning, besides benefiting the tree in general, may also remove many of the twig cankers in which the bacterium passes the winter, thus eliminating many of the sources of infection.

SUMMARY AND CONCLUSIONS.

(1) The peach bacterial spot, also known as bacteriosis, caused by *Bacterium pruni*, occurs in practically all peach-growing regions of the eastern half of the United States. It is most serious in the more southerly parts of this region. *Bacterium pruni* also causes a disease of the plum, affecting especially the Japanese varieties.

(2) Twigs, fruit, and leaves are affected, but the most serious injury is to the leaves.

(3) Experiments carried on by the writer and others indicate that the disease may be kept in check in southern peach orchards by proper pruning, cultivation, and especially fertilization. Nitrate of soda was by far the most efficient fertilizer used. Trees in which a high state of vigor and health is maintained are commercially resistant to the disease.

¹ Op. cit.

² For a discussion of peach tillage and fertilization, see Gould, H. P., Growing peaches: Sites, propagation, planting, tillage, and maintenance of soil fertility, U. S. Dept. Agr., Farmers' Bul. 631, 24 p., 7 fig. 1915.

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THE RED SPRUCE: ITS GROWTH AND MANAGEMENT.

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INTRODUCTION.

Spruce is one of the most important woods in the Eastern United States. It grows on large areas in pure or nearly pure stands, is distributed over many of the Northern States, and extends into the southern Appalachians at the higher altitudes. It is used more than any other wood in the manufacture of paper, and supplies a large amount of lumber and other material.

Various methods of forest management for spruce have been adopted by large lumber and pulp companies, of which spruce often forms the principal cut. The chief purpose of this bulletin is to formulate definite systems of forest management for various conditions.¹

USES OF SPRUCE.

Early in the history of the first New England settlement spruce became established as a valuable wood in shipbuilding, for framing, topmasts, and yards; and, where oak became scarce in the vicinity of the northern shipyards, it was used for ship knees. It soon found its way also into the export trade and was sent to the shipyards of

¹ The author's field investigations had to do chiefly with the spruce as it occurs in second growth. Accordingly, except for a reproduction study made in connection with the remeasurement of spruce permanent sample plots, the data and discussions concerning old growth or virgin conditions are based largely on an office study (1) of the material available in publications, of which the most important are the Adirondack Spruce, by Gifford Pinchot, Practical Forestry in the Adirondacks, by Henry S. Graves (Bulletin 26, Division of Forestry, U. S. Department of Agriculture), and the various annual forestry reports of Maine, New Hampshire, and New York, and (2) of the various unpublished data on spruce which have been collected by members of the Forest Service in times past.

England, the Continent of Europe, and the West Indies, where it was classed as a construction timber. Not until considerably later, however, did it assume a place of importance in the general market for carpentry and building use. When the supply of virgin white pine in New England declined, spruce was turned to as a substitute. Since 1840 the use of spruce as a lumber wood has steadily increased both in the domestic and foreign markets. Its rise as a raw material in the production of paper dates from about 1870 to 1875, although it was not until 1890 or 1895 that its consumption for this purpose became very important.

The most extensive single use to which spruce is put now is the making of paper, news stock, principally. Fully half the annual cut of red spruce is consumed by the paper industry.

Spruce is widely used in building and rough construction work, particularly where it is not exposed to the weather. In floors it wears better than white pine, but is inferior to many of the hardwoods. It retains its natural color when finished better than white pine, and it takes paint well. As interior finish it is employed for stair work, ceiling, and door, sash, and casing material. It also is made into shingles, siding, and laths, but as shingle material is considered inferior to many other woods. Large quantities are cut into joists, large dimension stuff, and car stock, since for its weight it is one of the strongest woods on the market. After being given preservative treatment to hinder decay it is employed for wharf and bridge piles, railroad ties, posts, and poles.

On account of the resonant quality of the wood, its even structure, the absence of vessels, the extremely fine and regularly distributed medullary rays, and the straight and long fibers spruce is generally considered to be the best wood for piano sounding boards, as well as for wooden musical instruments generally. For this purpose the wood must be of selected quality. It must be straight fibered and free from knots, and must have narrow and uniform rings and but little resin.

Spruce belongs to the class of tasteless woods, and for that reason is extensively used for containers in which articles of food are packed or handled, such as tubs, firkins, butterworkers, churns, fish barrels, and boxes and crates for vegetables and fruit. It is likewise in demand for boxes in which cans and bottles of salad and other table oils are packed for shipment.

Recently spruce has come into general use in the manufacture of airplanes. The wood meets satisfactorily the requirements of this industry, which demands lightness combined with strength and, above all, reliability, including freedom from hidden defects. It is used both for the upright posts and the general framework.

Minor uses of spruce are for matches, toys, clothespins, woodenware, sieve frames, cheese molds, and bandboxes. On account of its straight grain and light weight it finds a considerable use also in the manufacture of ladders, screen frames, cold-storage plants, refrigerators, pump stocks, furniture, canoe paddles, and light boat oars.

Two by-products of spruce may be mentioned. The resinous exudations are used as chewing-gum, and the claim is sometimes made that they possess medicinal properties. The extract made from the tender tips of the branches by boiling with water forms the basis of spruce beer, a nonalcoholic beverage formerly very popular, particularly among seafaring men, by whom it was considered a preventive of scurvy.

AMOUNT AND VALUE OF SPRUCE CUT AND IMPORTED.

Table 1 shows for the year 1909¹ the amount of spruce of all species utilized for different purposes, and the total and unit value of the material for each use. More than three-fourths of the total was red spruce.

Spruce ranked sixth in 1909 in the amount of lumber produced and contributed 3.9 per cent of the total for all woods. It was surpassed by yellow pine, Douglas fir, oak, white pine, and hemlock. In pulp production it ranked first and supplied 60 per cent of all the wood used. Nearly one-third of this, however, was imported. Spruce ranked ninth in slack stave production (3.6 per cent); twelfth in slack heading production (1.3 per cent); and ninth in the production of slack hoops (0.03 per cent), being surpassed in all of these minor uses by red gum, pine, beech, elm, birch, basswood, and maple. One per cent of the veneers produced in 1909 were of spruce, which ranked fourteenth among the species. In addition, 1 per cent of all the shingles, 0.2 per cent of all the railroad ties, 0.3 per cent of all the telegraph and telephone poles, and 2 per cent of all the cross arms produced in the United States were of spruce.

¹ Forest Products of the United States, 1909, Bureau of the Census in Cooperation with the Forest Service, Government Printing Office, 1911. This contains the latest complete enumeration covering minor as well as major forest products, which accounts for its use here in place of more recent data covering but a part of the field.

According to the census,¹ the reported production of spruce lumber remained practically stationary during the 10 years prior to 1909. The cut of 1909 was only slightly greater than that of 1907, and had the 1907 canvass been as complete it is probable that the 1907 production would have been found the greater, which indicates that the production of spruce lumber had then already passed its maximum. This assumption is borne out by subsequent figures, since in 1910 there were but 1,449,912,000 board feet produced, in 1913 but 1,046,816,000 board feet, in 1914 but 1,245,614,000 board feet, and in 1916 but 1,129,750,000 board feet.

In the consumption for pulp in 1907 spruce showed a decline in amount and in proportion to the other woods used. In 1910 there was a still further decline, followed by a slight recovery in 1911 to not quite so much as was consumed in 1909. In 1914 there was an increase over 1909 spruce pulpwood consumption of approximately 10 per cent with a total of 2,665,974 cords of which 1,957,487 cords was domestic spruce. By 1916 this gain amounted to approximately 30 per cent with a total of 3,143,793 cords of which 2,399,993 cords was domestic spruce. In both years the consumption of imported spruce was below that in 1909, which had to be made good by the domestic spruce supply. This was done at the expense of spruce lumber production which in 1909 made up 63 per cent of the combined total of pulp and lumber supplied by domestic spruce which in 1914 was but 56 per cent and in 1916 only 48 per cent. Notwithstanding this material increase in consumption of spruce for pulp the combined total of pulp and lumber supplied by domestic spruce decreased from 2,575,172,000 board feet in 1909 to 2,224,358,000 board feet in 1914 and 2,329,747,000 board feet in 1916. It is very evident that spruce lumber production was curtailed and a larger percentage of this high-grade material put into pulp notwithstanding that during the last two years European buyers of American forest products have increased their orders for spruce for all purposes abroad. Its accessibility in the east and its general all-round properties, including lightness, have made it much in demand.

In the use of spruce for slack cooperage and veneers in 1909 there was also a decrease, while in the number of railroad ties there was an increase due to the increasing use of chemical preservatives which made the less durable woods, such as spruce, more largely available for this purpose.

¹ Forest Products of the United States, 1909, Bureau of the Census in Cooperation with the Forest Service, Government Printing Office, 1911. This contains the latest complete enumeration covering minor as well as major forest products, which accounts for its use here in place of more recent data covering but a part of the field.

PRESENT STAND OF SPRUCE.

The amount of standing spruce timber in the United States,¹ according to recently revised estimates, is 116,500 million feet board measure, or 4 per cent of the total standing timber of all kinds. This stand is divided among the three commercial spruce regions as follows: The eastern or red spruce region, 48.3 per cent;² the Rocky Mountain or Engelmann spruce region, 30.3 per cent; and, the Pacific coast or Sitka spruce region, 21.4 per cent.

The commercial stands of spruce timber in the eastern spruce region by States are given in Table 2.

TABLE 2.—*Stand of spruce in the eastern or red spruce region.*

State.	Billions of board feet.	Per cent.
Maine.....	26.0	46.2
New Hampshire.....	5.9	10.5
Vermont.....	1.4	2.5
Massachusetts.....	0.9	1.6
New York.....	13.3	23.6
Maryland.....	0.2	0.3
West Virginia.....	8.6	15.3
Total.....	56.3	100.0

VALUE OF SPRUCE AND SPRUCE STUMPAGE.

In total value of annual lumber production in 1909 spruce stood sixth among the woods, with 4.3 per cent of the gross output, and in unit value of the manufactured product it stood fifteenth, with a value of \$16.91 per 1,000 board feet. It was surpassed in total value by yellow pine, oak, white pine, Douglas fir, and hemlock; and in unit value by walnut, cherry, hickory, yellow poplar, ash, oak, cypress, cedar, basswood, white pine, sugar pine, cottonwood, elm, and birch.

Table 3 shows the value of spruce stumpage by States, based both on estimates and on reports of sales collected by the Forest Service for the years 1907 and 1912. As a means of comparison the table includes the values for spruce in the Lake States, Rocky Mountain, and Pacific Coast States for these same years; also the census figures for all spruce for the years 1899 and 1904.

The range of 1912 values was from \$1 to \$11 per thousand, according to estimates, and from \$2 to \$11, according to sales. The minimum estimated value, \$1, was reported from North Carolina; and

¹ Unpublished estimates of the "Standing Timber in the United States," prepared by the Section of Computing, Forest Service, February, 1915.

² The amount of spruce of commercial size remaining in the Lake States was apparently too small to be expressed in terms of billion feet. This is doubtless also true of other States, as those in the southern Appalachians, omitted from Table 2.

the maximum from New York. North Carolina, Tennessee, and Virginia each reported \$2 sales, and New York reported maximum price sales, \$11.

In seven of the red spruce States, Maine, New Hampshire, Vermont, New York, Maryland, North Carolina, and Kentucky, there was a rise in stumpage values from 1907 to 1912, while in the remainder there was a decline. Leaving out of consideration Maryland and Kentucky, where the number of reports is too small to form a reliable basis, the greatest rise took place in New York and showed a gain of 25 per cent and 35 per cent on the basis of estimates and of sales, respectively. The next greatest gain was in North Carolina, where a rise of 21 per cent is indicated on the basis of 16 estimates. Vermont ranks third in percentage of increase; New Hampshire, fourth; and Maine, with the largest number of reports, shows the least increase in values, 6 per cent according to estimates and 3 per cent according to sales. New York also ranks first in the greatest actual increase, namely, \$1.44 and \$2, according to estimates and to sales, respectively, followed by Vermont, New Hampshire, North Carolina, and Maine, in the order named.

TABLE 3.—*Stumpage values of spruce.*¹ALL SPECIES OF SPRUCE.²

State.	1912				1907	
	Average per 1,000 feet from estimates.		Average per 1,000 feet from sales.		Average per 1,000 feet.	
	Value per 1,000 board feet.	Number of reports.	Value per 1,000 board feet.	Number of reports.	Value per 1,000 board feet.	Number of reports.
All States reporting.....	\$4.54	488	\$4.16	175	\$4.35	383

EASTERN (RED) SPRUCE.

All Eastern States.....	\$6.11	236	\$5.90	78	\$5.53	164
All Northeastern States.....	6.50	205	6.32	70	5.93	114
Maine.....	6.09	102	5.93	37	5.74	34
New Hampshire.....	6.78	28	6.54	13	6.07	21
Vermont.....	6.82	25	6.72	9	5.87	31
Massachusetts.....	6.50	14	5.00	3	7.07	7
New York.....	7.25	36	7.81	8	5.81	21
All Appalachian States.....	3.51	31	2.15	8	4.62	50
Pennsylvania.....	6.37	4	.....	.....	8.00	12
Maryland.....	4.50	3	.....	.....	3.33	3
Virginia.....	3.00	3	2.00	1	3.61	9
West Virginia.....	4.17	3	.....	.....	4.63	15
North Carolina.....	2.52	16	2.33	6	2.08	6
Kentucky.....	6.00	1	.....	.....	1.63	2
Tennessee.....	2.00	1	2.00	1	2.50	3

¹ The values per cord for pulpwood may be roughly approximated by halving those given in the table, although the common practice in the northern spruce country is to figure a cord equivalent to 600 board feet.

² The census gave the average values of spruce stumpage for all States as \$3.70 per 1,000 feet in 1904 and \$2.26 per 1,000 feet in 1899.

TABLE 3.—*Stumpage values of spruce—Continued.*

LAKE STATES (WHITE) SPRUCE.

State.	1912				1907	
	Average per 1,000 feet from estimates.		Average per 1,000 feet from sales.		Average per 1,000 feet.	
	Value per 1,000 board feet.	Number of reports.	Value per 1,000 board feet.	Number of reports.	Value per 1,000 board feet.	Number of reports.
All Lake States.....	\$4.68	94	\$4.59	20	\$5.60	99
Wisconsin.....	4.63	38	4.67	9	6.16	37
Michigan.....	5.04	29	4.79	6	5.21	47
Minnesota.....	4.36	27	4.20	5	5.47	15

ROCKY MOUNTAIN (ENGELMANN) SPRUCE.

All Rocky Mountain States.....	\$2.12	78	\$2.37	51	\$1.87	52
Montana.....	2.07	21	2.13	11	1.83	8
Wyoming.....	2.28	8	2.47	8	2.00	2
Idaho.....	1.71	14	2.41	6	1.73	11
Utah.....	2.15	5	2.30	7	1.64	7
Colorado.....	2.31	25	2.45	14	2.00	22
Arizona.....	2.00	2	2.00	1	.....	.....
New Mexico.....	2.50	3	2.67	3	1.94	2
Nevada.....	.....	.....	3.00	1	.....	.....

PACIFIC COAST (SITKA) SPRUCE.

All Pacific States.....	\$2.10	80	\$2.10	26	\$1.58	68
Washington.....	2.26	52	2.41	16	1.73	46
Oregon.....	1.90	20	1.54	8	1.40	14
California.....	1.56	8	1.87	2	1.03	4

The number of reports from the remaining five Eastern or red spruce States which show a shrinkage in values is entirely inadequate for a reliable estimate of stumpage price tendencies. It is possible, however, that in such States as Massachusetts and Pennsylvania, where the amount of spruce was never extensive and where cutting has been going on for many years, there is in fact an actual decline in values due to the poor quality of timber now available for cutting. This also may be the situation in Maryland, Virginia, and Kentucky. In West Virginia, North Carolina, and Tennessee, however, the apparent decline is doubtless due to an insufficient number of reports, since the virgin spruce growth in these States is of choice quality, and much of it is in localities which are just now being developed.

Eastern spruce in 1912 showed the second highest average stumpage value of 20 softwoods and the ninth highest of 38 softwoods and hardwoods combined.¹ It was exceeded in value by cherry (\$16.25), walnut (\$15.64), pine (\$8.35), ash (\$7.87), yellow poplar (\$7.87), hickory (\$7.82), basswood (\$7.70), and oak (\$7.28).

¹ Compiled from estimates on all species reported in 1912.

Too much dependence can not be placed on any of these values except for the purposes of general comparison, for the reason that through a process of adulteration of the purity of the product, so to speak, the true rise in value for a period of years is not shown by average stumpage price quotations. To illustrate: The average stumpage values per 1,000 feet in a certain locality might have been \$2 twenty years ago, \$3 ten years ago, and \$4 to-day, while the quality of the cut in those years might have been 100 per cent first quality 20 years ago, worth \$2 per 1,000 feet, 67 per cent first quality 10 years ago, worth \$4, and 40 per cent first quality to-day, worth \$8, the differences being made up in the latter instances by cheap, low-grade material which 20 years ago could not have been given away. Thus the true rise in stumpage value, instead of being from \$2 to \$4, as indicated by the average stumpage figures, should be \$2 to \$8, based on the same class of product throughout the period. This is but one of many similar conditions which help to obscure the true rise which has taken place and is taking place not only with spruce but with all stumpage and which must be understood in making use of any general stumpage figures.

RANGE AND DISTRIBUTION.

Regarding the range and distribution of red spruce, the various botanical authorities are in disagreement. This condition arises largely from the fact that the red spruce and the closely allied black spruce are not perfectly distinguishable under some circumstances. When red spruce is segregated from the black spruce, its range is given as from Prince Edwards Island to the valley of the St. Lawrence River, southward to the coast of Massachusetts, along the interior hilly parts of New England and New York to the Allegheny Mountains, to western North Carolina, eastern Tennessee, and the higher peaks of South Carolina. When the black and red spruce are considered as a single species, the range extends, in addition to the above, from Labrador and Newfoundland to the valley of the McKenzie River in latitude about 65° north and, crossing the Rocky Mountains, from the interior of Alaska to the valley of the White River and from the eastern foothills of the Rocky Mountains in Alberta through northern Saskatchewan and northern Manitoba to central Wisconsin and Michigan. The accompanying map (fig. 1) shows these ranges graphically as well as those for the other species of this genus which are indigenous to the United States.

The red spruce occurs chiefly on well-drained uplands and mountain slopes. In the northern portion of its range it is found on the better-drained soils at or near sea level. Within the United States its commercial range is rarely below 1,000 feet elevation, although under some conditions it may extend somewhat lower, as, for instance, in swamps. In these situations the red and black spruce find their

common meeting ground and approach each other so nearly in character of growth and appearance that it is difficult to determine at what point the one entirely supersedes the other. Red spruce is also found in small groves along the seacoast of southern Maine and northern Massachusetts. Spruce, presumably red spruce, is to be found in small parcels at between 200 and 500 feet elevation on the low rolling uplands of eastern Maine, where it has taken possession of old abandoned pastures.

The upper limit of its range within the United States is at timber line, although in the Northeastern States its commercial limit may

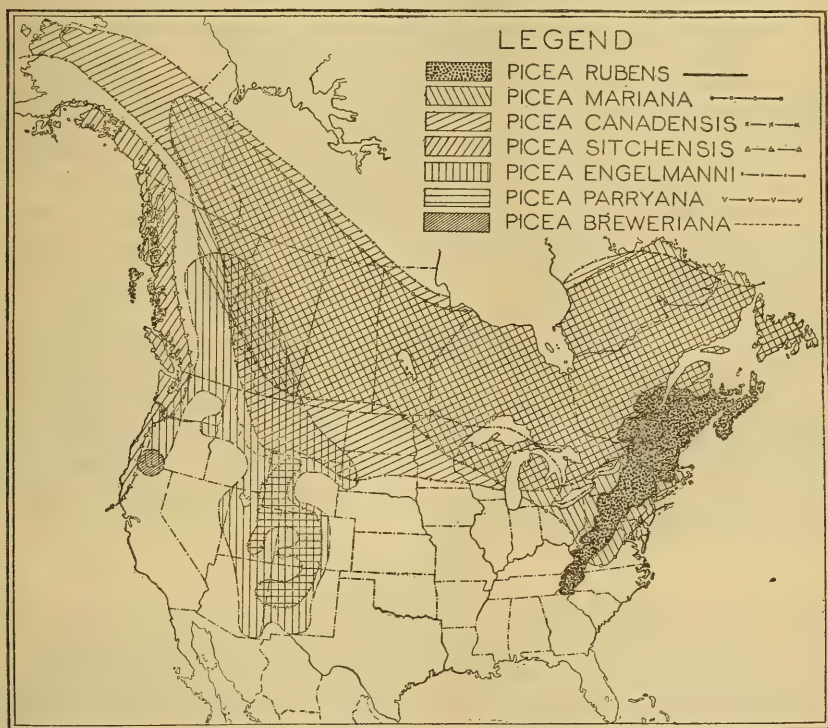


FIG. 1.—The botanical range of spruce.

be set at about 4,000 feet above sea level. In Maryland its minimum altitudinal range is 2,500 feet above sea level and constantly rises toward the southern limits of its occurrence in northern Georgia. It probably reaches its commercial upper limit between 5,000 and 6,000 feet in the mountains of North Carolina and Tennessee.

FOREST TYPES.

The old growth forests of the spruce region may be divided into four main types. The names chosen here for these types are those commonly used by lumbermen in describing them according to the various situations on which they occur.

The relative importance of the four types varies according to the locality. In the mountainous portions of central Maine the mixed hardwood lands and spruce slopes are of greatest importance, while in the northern part of the State the spruce flat is the more prevalent. The spruce slope is the characteristic type in the White Mountain region. In the Adirondacks the mixed hardwood type is the most common, followed by the spruce swamp and the spruce slope. In the southern portion of its range spruce is only sparingly associated with hardwoods, the spruce slope type being more prevalent.

SPRUCE SWAMPS.

The spruce swamp type dominates the low-lying, poorly-drained areas, whose soil is a muck or peat, spongy in texture, and acid. The characteristic species are red spruce, black spruce, balsam, tamarack, cedar, soft maples, black ash, and other moisture-loving trees. Sphagnum moss and low water-loving herbaceous plants commonly form the undergrowth. Spruce usually makes a slow growth in such situations, and is short and scraggly in appearance. It is particularly susceptible to windthrow on these soils, which prevents its attaining as large size or as great age as when growing on the better types of soil. Even-aged stands are not at all uncommon. Numerous small islands of drier and firmer soil texture are scattered throughout this type of soil. They support a somewhat better growth of spruce, mixed with hemlock, white pine, birch, and some beech and sugar maple. Balsam, tamarack, or arborvitæ will not infrequently be found predominating in the wetter portions; and black spruce is largely confined to such places.

SPRUCE FLATS.

The level and rolling flats bordering the swamps, lakes, and water-courses, are occupied by the spruce flat type. The soil is variable in composition, moderately deep where sandy or gravelly in texture, and shallow where stones and boulders predominate. While the percentage of moisture may be high, the drainage is free and a favorable condition is afforded for thrifty tree development. The flat type is in large measure a transition between the swamp type and the type of the mixed hardwood lands, and in many respects exhibits the characteristics of each. Spruce, birch, soft maples, white pine, hemlock, and balsam are the characteristics trees in mixture. The presence of black ash, which is usually accompanied by considerable balsam, denotes conditions bordering on the swamp type. The presence of sugar maple, on the other hand, denotes a transition to the hardwood lands. White pine of good quality formerly occurred in abundance in this type in both Maine and the Adirondacks, particularly where a sandy soil predominated. Spruce attains an inter-

mediate development here, while birch and the better hardwoods are inferior in development as compared with the same species growing on the hardwood lands. Hemlock and red maple find the best conditions for their development in this type. Windfall is not uncommon, and as a result young even-aged stands of spruce are found occupying the ground where this has taken place. Second-growth stands of birch and red maple may also be found occupying such areas.

MIXED HARDWOOD LANDS.

The mixed hardwood type occupies the best soil sites of the region, usually the benches and the lower mountain slopes. The soil is here best adapted to hardwood growth, is deep, of more or less even texture, fresh, and well-drained. Besides spruce, sugar maple, beech, and birch predominate, and there is a scattering of hemlock, white pine, soft maple, cherry, and a variety of other species. The proportion of spruce in mixture depends on topographic conditions. On gentle slopes, broad benches, and low ridges the hardwoods find conditions so favorable to their development that the spruce is largely crowded out. The more irregular and broken topography enables the spruce to compete with the hardwoods on more nearly equal terms. What spruce lacks in reproductive power it makes up by its superior ability to grow on the rougher, thinner soils. The broken topography undoubtedly favors spruce on account of the higher percentage of moisture to be found in the soils of the protected coves and slopes than in those of the gentle and more regular slopes of uniform exposure. Spruce attains its maximum development in the mixed hardwood type, as do also most of the hardwoods.

SPRUCE SLOPES.

The slope type occupies the steeper slopes, with thin, stony soil, above the hardwood land, and may extend to the limits of tree growth, although not infrequently it gives way to a scrubby alpine growth composed almost exclusively of balsam. The type is characterized by a nearly pure coniferous growth with spruce predominating. Balsam is also present in appreciable quantities. The characteristic hardwood is yellow birch, which is generally of excellent quality. Hemlock, white pine, and a variety of hardwoods occur sparingly in the lower portions of this type or on the better soils of the lower ridges. Spruce of good quality, with tall, clean boles, closely set together in a dense stand, is produced on this type. As compared with the hardwood lands, spruce development is inferior here on account of the greater liability to windfall and poorer soils. Also because of the liability to windfall the forest is often comparatively young.

SECOND-GROWTH STANDS OF SPRUCE.

Partial or complete destruction, such as is effected by lumbering, windfall, or fires, will alter more or less completely the original character of any of these types, depending on the severity of the cutting or the extent of the windfall or fire. The succeeding second growth will develop a strong tendency to produce a groupwise association of the species, which in case of extended destruction may effect a temporary replacement of the original growth by either of two general forms—pure, even-aged stands of spruce or balsam alone or in mixture with each other, hemlock, arborvitæ, and hardwoods, or a two-storied form comprising an over wood, usually of such hardwoods as aspen, grey birch, fire cherry, and the like, and an understory of spruce. The last named is the typical one following fire. Nevertheless, if left undisturbed, the characteristics of these stands will usually revert to those of the parent type.

OLD-FIELD SPRUCE.

Because of their economic possibilities, particularly as forecasting the results which may be expected from plantations, the old-field spruce stands merit special mention. As their name implies, they occupy abandoned lands formerly under cultivation or in pasture. They are essentially even-aged and composed chiefly of spruce. Hereafter the discussion of second growth will refer to this character of the stand unless otherwise specified.

SOIL AND MOISTURE REQUIREMENTS.

Spruce is found on all kinds of soil. It is not exacting in its demands as to chemical composition, but prefers the well-drained gravelly and sandy loam soils of the mountain slopes and benches because of their favorable moisture conditions. Heavy soils are unfavorable to spruce because they hinder root penetration, accentuating its shallow rootedness, and thus render it more than ever liable to windthrow.

Moisture is the most potent factor influencing the local distribution of spruce on the various soils. Soils like sand or coarse gravel, which are devoid of binding material, quickly lose their surface moisture. They therefore afford scant opportunity for the development of spruce, even though the water table is but a few feet below the surface, since the water can not be reached by the superficial root system. Spruce can endure a wet soil, such as the clays and fine alluviums occurring in swamps. It reaches its best development, however, on the intermediate gravelly or sandy loam soils with free drainage, yet with a plentiful supply of surface or subsurface moisture.

Aside from these preferences of spruce, its distribution is dependent largely upon its ability to grow on sites unfavorable to its competitors. Spruce is not infrequently found almost solely in possession of large

areas on steep, rocky mountain slopes or wet bottom lands. Competition with the hardwoods is reduced both by their inability to adapt their root systems to the shallow soil and by excessive moisture conditions. Thus spruce is found most abundantly, not where the best conditions for its own growth exist, but where its competitors are not readily able to grow.

On the more favorable soils such agencies as fire, windfall, and fungous or insect attacks may prove a means by which the extension of spruce is made possible, provided a sufficient number of spruce seed trees remain to seed up quickly the ground formerly occupied by its competitors.

LIGHT REQUIREMENTS.

Spruce is one of the most tolerant of shade of our forest trees. Of the associates, only hemlock, and possibly sugar maple and beech, are more tolerant.¹ Spruce also possesses to a remarkable degree the power to recover and grow in a thrifty and normal manner following its release from long periods of suppression. Having once gained a foothold in the selection forest, the young spruce grips life tenaciously, struggles along for many years under the shade of the forest, and gradually forces its way upward as natural thinning reduces the number of its overtopping competitors. It is in fact to these qualities more than any others that spruce owes its ability to persist as a factor in the mixed selection forest of the Adirondacks, in the Northeast, and throughout its range.

Strangely enough these tolerant and recuperative qualities are most characteristically displayed by spruce in the selection forest. In the dense, even-aged pure stands, root competition and mechanical interference due to overcrowding enter in to complicate the situation. Trees which are suppressed under these conditions recuperate very slowly, if at all. Most often, when the stand is opened up sufficiently to afford the requisite amount of light and growing space, the suppressed crown is so reduced in size and vitality as to make recuperation imperceptible for a period of years. Such suppressed trees when released from overcrowding often succumb to windthrow or sun-scald.

Balsam although moderately tolerant is less so than spruce, the keen rivalry between the two species being due to other qualities in which balsam surpasses spruce.

WINDFIRMNESS.

Unlike most hardwoods and some of the conifers, notably the yellow pine and Douglas fir of the West, spruce develops a very superficial root system. On account of the intimate relation between the root and the crown of a tree and the active competition of root sys-

¹ Under the keenly competitive conditions which prevail in even-aged second-growth stands, spruce is able readily to suppress and kill out even these species.

tems, particularly those of the shallow-rooted species, spruce is much less windfirm when growing in crowded or pure stands than when growing in the open or in mixture with hardwoods. Thus the relative size and the form of the crown of spruce growing under different conditions of density and association is an index of its comparative windfirmness.

REPRODUCTION.

SOIL, MOISTURE, AND LIGHT.

Spruce finds its most favorable conditions for germination and subsequent early growth on the moist forest floor under cover of the not too dense stand of the selection forest. Here a suitable seedbed of moss, dead wood, and needle litter is found, which, being protected from exposure to the drying influences of sun and wind, affords sufficient moisture for germination and early development. That spruce appears to be selective in its seedbed requirements, and that observers are in disagreement as to whether it does better on mineral soil or on moss, dead wood, or duff, is largely because so much depends upon the moisture conditions in the different materials.

A plentiful supply of soil moisture is absolutely essential, not alone at the time of germination but throughout the period when the young plant is becoming established. This condition can be most readily obtained, and with the minimum amount of free moisture in the form of precipitation and seepage, under cover of the forest. That spruce will germinate and continue to grow and thrive on mineral soil can not be gainsaid, but only when such soil is protected from drying influences and is plentifully supplied with a constant amount of available moisture at or very near the surface. The same applies to needle litter and old logs.

Needle litter when under a pure stand of spruce, particularly dense, unthinned, even-aged stands, is apt to accumulate much more rapidly than it will disintegrate. The upper layer forms a loosely compact mantle, which rapidly loses its surface moisture when exposed to drying influences. In the early spring or late fall, when humid conditions prevail, this mantle of needle litter contains sufficient moisture to induce germination, but the young plants are soon after destroyed by frost or drought. Furthermore, it is difficult for the young seedlings to extend their root systems through the litter to mineral soil. In consequence, it is not suitable for a seedbed, and in fact, under such circumstances, is a great detriment to reproduction. If no great depth of such litter exists, so that the disintegrating humus layer is practically at the surface, the seedbed is admirable, since the humus is very retentive of moisture, and the vegetable mold full of nourishment. Acid humus, however, is not suitable, for though it is most common in supermoist situations it is physiologically dry. The same general considerations that apply to needle litter apply to a still greater extent to the leaf litter from hardwoods, since, particularly

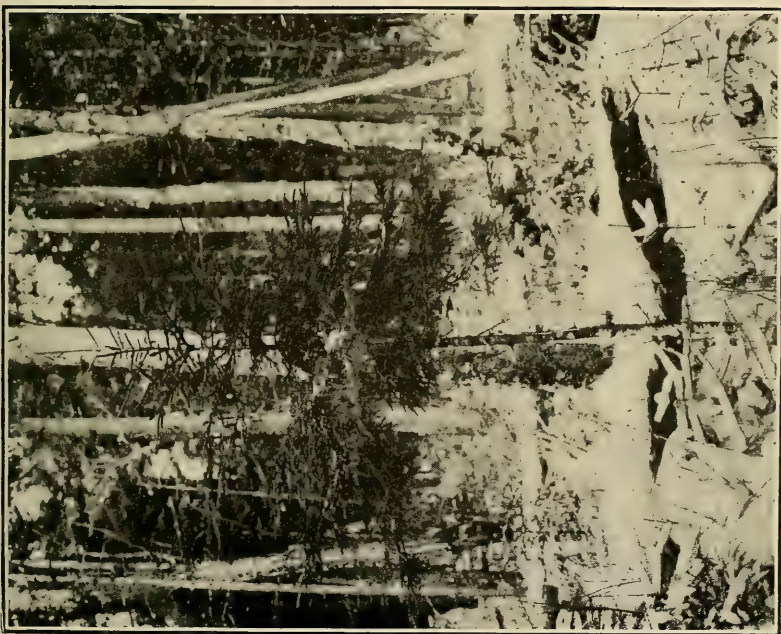


FIG. 1.—UMBRELLA FORM DEVELOPED UNDER VIRGIN FOREST CONDITIONS, SHOWING RECOVERY FROM SUPPRESSION.

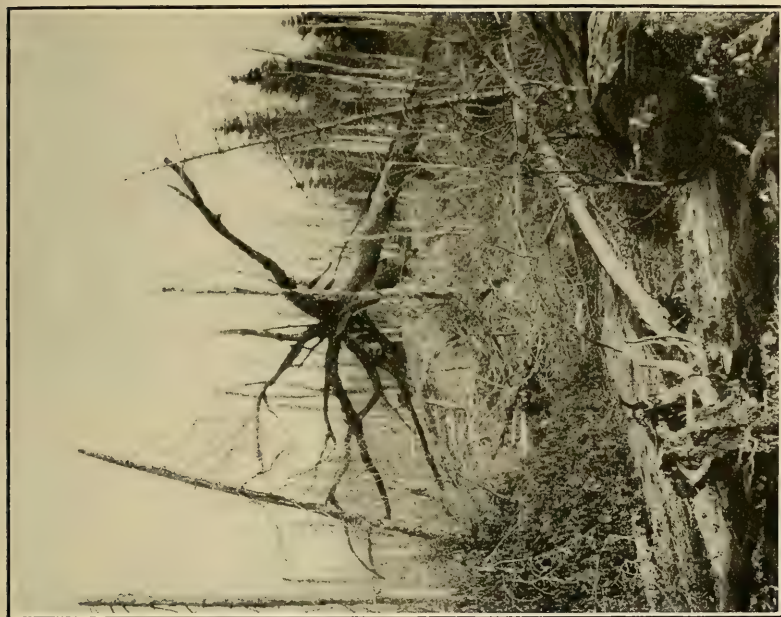


FIG. 2.—A WIDESPREADING AND SUPERFICIAL ROOT SYSTEM; TREE OVERTURNED AFTER FIRE HAD BURNED OUT THE THIN SOIL OVERLYING THE ROCK.

CHARACTERISTICS OF GROWTH.



FIG. 1.—IN THE VIRGIN FOREST.



FIG. 2.—IN AN OPENING MADE BY A CUTTING 12 YEARS PREVIOUS.



FIG. 3.—UNDER A STAND OF WHITE BIRCH AND POPLAR ON A BURN OF 40 YEARS AGO.
SPRUCE REPRODUCTION.

in the case of the thicker leaved hardwoods like maple, the duff not only sheds water and thus dries out quickly at the surface, but it also offers a considerable resistance to the root penetration of the germinating spruce seedlings.

The presence of moss is simply an indication of the presence of surface moisture throughout the growing season in sufficient amount to afford favorable conditions for spruce germination. An unbroken grass sod hinders the reproduction of spruce, both because it resists the progress toward the mineral soil of the rootlets of the young plant and because it makes excessive demands on subsurface moisture. In very moist and wet situations grass sod is seldom continuous, and in such places spruce has no trouble in starting under the cover and protection of the rank growth.

Protection from direct insolation and wind is also of importance, since they not only cause the drying out of the upper layers of the soil but induce rapid transpiration from the leaves of the young plants. This latter is particularly disastrous in the winter season when the soil is frozen and the seedlings are prevented from replenishing from the soil the supply of moisture thus given off. Such a condition is most likely to develop during a season of little snow, or where through exposure to an unbroken sweep of wind the snow has little chance to accumulate. In these open, bare situations, also, a warm day causing rapid thawing may be followed by freezing at night, which loosens the soil around the roots of the seedling and thus allows these tender members to be exposed to drought and frost.

In addition to moisture, a certain amount of light is absolutely necessary if the seedling is to endure beyond the period of germination. Since, however, spruce does not make extravagant demands in its light requirements, little difficulty is encountered in securing suitable conditions in this respect.

SEED PRODUCTION.

Authorities vary widely in their estimates of the frequency and abundance of spruce seed production. So far as is known, no observations have been carried on over a sufficient period of years to determine this with any degree of certainty. Spruce unquestionably produces a certain amount of seed annually, and conditions may be such that a good crop will occur for two successive years. In general, however, the interval between succeeding full seed crops varies from three to seven or eight years.

Spruce produces from 50 to 90 per cent perfect seed; from 60 to 80 per cent of which germinate. The seeds retain their vitality for at least two years under ordinary conditions of storage, and probably much longer. Variations are due to the conditions in the seed year. An off year not only produces fewer seeds, but the quality is poorer.

The age at which spruce begins to bear seed of good quality varies widely, depending on the soil quality, the exposure, and whether the tree is growing in the open or in the forest. In the virgin forest the production of seed is only indirectly a function of age and is more directly dependent upon size. The individual tree varies greatly as to the age when it becomes freed from suppression and enters upon a normal stage of development, thus gaining for itself a place in the full light of the upper crown classes. It appears from a study of the spruce made by the Bureau of Forestry¹ in cooperation with the Forest Commission of Maine in 1901, that in no case was a tree smaller than 5 inches in diameter at breastheight found bearing cones. The average age of spruce of this size in the virgin selection forest may be placed at about 100 years and in even-aged second-growth stands at from 20 to 30 years. Other observers have reported forest grown trees of three or four inches in diameter bearing seeds wherever their crowns were not directly under the shade of some other tree. The largest quantity and best quality of seed is produced in the virgin forest by trees from 10 to 18 inches in diameter at breastheight. In other words, spruce in the forest begins to bear seed when the crown succeeds in reaching the light, and begins to bear heavily when the top of the crown thickens. At first a few cones are borne near the main stem below the last year's growth, and as the crown thickens and spreads the cones are borne on the side branches. The first seed produced is of very poor quality.

In the open and under favorable soil and exposure conditions, seed production begins as early as the fifteenth or twentieth year, and heavy crops follow by the thirtieth or the thirty-fifth year. In the dense, even aged second-growth spruce stands the cones begin to be sparingly formed about the thirtieth year under the most favorable conditions; but a safe average for initial seed production in such stands would be not earlier than from the thirty-fifth to the fortieth year, with a full crop production about five or ten years later. Spruce continues to bear seed to an advanced age.

Spruce seeds begin to mature between September 15 and October 1, depending upon climatic conditions. Seed collecting, therefore, can be most profitably confined between these dates; or if a larger amount of seed is required than can be collected during this period, the work should be begun earlier and timed so as to reach completion by October. Upon full maturity the cones open and many of the seeds fall out, although not all, for frequently a considerable amount of seed can be seen on the surface of the late snows in February and March. After the cones are fully matured they are easily dislodged during lumbering; but if they are not disturbed, they remain on the trees until the next spring or early summer. The seed is light and winged

¹ Now the Forest Service.

and thus can be carried a long distance by the wind, variously estimated at from one-fourth to one-half mile. Its effective range under ordinary conditions is, however, very much less than that, probably not more than 200 feet.

COMPETITIVE DISADVANTAGES.

Spruce is subject to considerable competition with other species for the possession of the ground. In the mixed softwood and hardwood stands, beech and maple are its chief competitors; and in the softwood stands, balsam. Such species as witch hobble, briars, and the like often take possession of the ground after logging or fire, also fire cherry, aspen, and birch. These latter, however, soon open up their crown cover sufficiently to admit of spruce coming in beneath. The competition where briars and their associates occupy the ground after extensive cuttings or fire, is largely a matter of unfavorable seed-bed conditions.

The competition of balsam, on account of its close association with spruce, is of vital importance. It almost invariably happens that on the replacement of stands where these two species occur in mixture, balsam largely predominates in the second growth. Balsam possesses the two distinct advantages over spruce of a plentiful supply of seed annually and of a decidedly more rapid growth, particularly in the seedling stage. While the moisture, seed bed, and to a great extent the light requirements are about the same for both, the more rapid growth of balsam enables it to extend its root system more vigorously and thus become established more quickly and more firmly under seed-bed conditions in which spruce, although germinating with equal facility, is later exterminated through subsequent drying out of the upper layers before its roots have become firmly established. Soil acidity under spruce growth is supposed to be inimical to the development of the spruce seedling, while the balsam seedling is unaffected by it. Spruce, however, will come in under balsam without difficulty. This has led to the supposition that a balsam growth must intervene between successive growths of spruce in order to "sweeten" the soil.

While the theory may be true, a contributory cause at least may be found in the character of the litter under the two stands. Spruce needle litter, particularly under dense forest conditions, is very resistant to decay. It thus has a tendency to accumulate faster than it can be decomposed, forming an inert soil cover of considerable depth, resistant to root penetration and porous, quickly draining away the water close to the surface so much needed by the small, slow-growing root system of the young spruce seedlings. This handicap the more vigorously growing balsam seedling is able to overcome so as to establish itself in place of the spruce. But balsam needle litter, decaying much more readily than the spruce, does not accumu-

late undecomposed to anything like the extent that spruce litter does. Thus the moist humus layers lie close to the surface and materially aid the young spruce to get established.

Further than these, however, a condition was recently observed which, if noted by other observers, has not been mentioned before in any published work on the spruce and which places the spruce at a still further disadvantage in its competition with balsam and with hardwoods as well. During the examination of the forest floor under the normal cover of even-aged spruce stands in the latter half of September (1910), a large quantity of germinated spruce seed was found which must have been from the recently ripened seed crop, since only the seed leaves were developed, and in many cases even the seed-coat still enveloped the tips of the embryonic leaves. These spruce germinates were so thick in places as to make it impossible to place a finger on the ground without crushing several. Balsam seedlings were also found, but remotely scattered as single individuals and almost without exception spring germinates, with well-developed stems and permanent leaves. One and two year old balsam seedlings were also present. Spruce of this age was entirely lacking, and seedlings of the previous spring's germination were also only sparingly represented.

Balsam seed trees were not very numerous, so that this condition did not of itself indicate much with relation to the behavior of that species; but subsequently a stand of almost pure balsam, within a short distance of the spruce plot just mentioned, was examined. Here, although the site was not quite the same, the density of the cover was very similar and in places conditions were even more favorable to germination and early growth than in the spruce stand. A close examination of the humus and light moss cover failed to disclose more than a scattering of balsam fall germinates, although the presence of new sound seeds in considerable quantity was disclosed. Balsam seedlings from spring germinates were plentiful, occurring as individuals, while 1 and 2 year old seedlings were also numerous.

In contrast to this condition spruce in the young growth of open pastures was observed to be much more prevalent than balsam. In explanation of this apparent reversal of the reproduction capacities of the two species, it seems entirely probable that in the fall soil moisture and general climatic conditions are, in the open, much less favorable to germination of spruce than in the forest. Furthermore, the principal seed distribution of spruce in the open, except in the immediate vicinity of seed trees, doubtless occurs later in the season from seeds subsequently dislodged from the cones by the winter storms. Thus in the open a relatively larger percentage of spruce seeds would lie over for spring germination with a correspondingly better chance of becoming permanently established.

As to the less favorable showing of balsam, this was unquestionably due in part to the smaller production of balsam seed, since there were fewer balsam than spruce seed trees in the particular locality where conditions were observed. Then, too, balsam seeds are heavier than those of spruce, so that they would not be carried so far by the wind, and balsam seedlings are also browsed by cattle much more than spruce.

If this behavior of spruce and of balsam in regard to time of seed dispersal and germination is typical of the two species, it can be readily seen that even with a less production of fertile seed than spruce, balsam would have a considerable advantage. The fall germination of spruce would subject the very young seedlings to a material reduction in numbers and vitality during the first winter as a result of winter-killing, while the loss to balsam from this cause would be comparatively insignificant.

Spruce is at a disadvantage, too, in its early struggle for a foothold in mixed hardwood stands. The usual explanation for its failure to come in more plentifully under a mixed hardwood forest after cutting is that the abundance of hardwood leaf litter on the ground at the time of seed fall prevents the spruce seeds germinating thereon from getting their roots into mineral soil, both because of the tough and impenetrable texture of the birch, maple, and other hardwood leaves and because the loosely compact surface layer of leaves sheds the moisture and quickly dries out before the young spruce can get established. While these undoubtedly are among the contributory causes, observations made in Waterville, N. H., in the spring of 1911 in connection with spruce reproduction plots under hardwoods suggest that here again the early seed dispersal habit of spruce works to the disadvantage of its reproduction. On several of these plots after the leaf litter of the previous fall was removed a considerable number of spruce germinates of that spring were counted. Many, however, were either wilted or had already succumbed to "damping-off," while others were bleached almost white and the stem and leaves were turgid and succulent, but without vigor, doubtless from too humid growing conditions and lack of sufficient light. This was particularly noticeable under moosewood and young hardwood brush with large coarse foliage. The absence of any one-year or two-year spruce on these plots was also noticeable. A marked contrast to this condition was found where any part of these plots happened to be protected from the heavy hardwood leaf fall by a group of suppressed spruce or small balsams or a pile of slash. Here there would be a generous number of spruce germinates and one and two year seedlings as well. In fact, reproduction appeared to be entirely satisfactory.

Whether fall germination takes place in these circumstances or not, the seeds, or germinates, will be covered with a thick layer of

hardwood leaves. In the spring the warm rains and sun start fermentation of this mulch, and while this at first affords conditions exceedingly favorable to the germination of the spruce seed, the young seedlings are unable to survive the continued heat and humidity and the general smothering effect of the hardwood leaf litter. The trouble thus seems to be not that the seedlings are unable to get their roots into mineral soil or other suitable material as is usually claimed, but that the heavy mulch prevents them from getting their shoots up into the needed light and air.

FORM.

The form of spruce varies widely and is determined largely by its stage of development and whether it grows in the open or in the forest. Like all other conifers, however, it always develops a well-defined central axis. In the open and before arriving at the stage in the forest where its lower limbs begin to be suppressed, spruce has a long, wide-spreading, conical-shaped crown, which extends well down to the ground. Its bole tapers rapidly. This form is retained to a large extent throughout life by the trees growing in the open, although their crowns open out and become less regular in outline with advancing age. In the forest the crown is more compact and has a conically topped head. As the tree grows in height the crown becomes shorter in proportion to the total height through the lower branches dying out more rapidly than new ones can be produced above. The bole at the same time takes on a more cylindrical form below the crown. Trees growing in the selection forest are likely to taper a little more rapidly than those in the even-aged stands, since they receive more side light and thus retain a longer crown than the more densely crowded, even-aged ones.¹

LENGTH OF LIFE AND MAXIMUM SIZE.

Spruce may be classed as one of the longest-lived trees in the eastern United States, ranking with the white oak in this respect. In a virgin stand spruce seldom matures under 200 years, and the average age of the trees in such stands is undoubtedly nearer 250 or 300 years. According to Mr. Austin Cary, the oldest spruce which came under his notice in Maine was approximately 400 years (372

¹ An example of the variable form and development of spruce growing under different conditions is shown in the following abstract from a memoir on the Adirondack spruce by the late Col. W. F. Fox, Superintendent of State Forests, in the Report of the Forest Commission, State of New York, 1894: "A spruce 20 inches in diameter growing in a clump of spruces will yield five logs 13 feet 4 inches in length, while one of the same diameter in a scattered growth mixed with hardwoods will yield but four logs. In the one growing among hard woods after four logs have been cut from the trunk the diameter of the last or top log at its small end will be from 10 to 12 inches, but the limbs above this point will be so thick and large that the fifth log would not be over 5 or 6 inches at the top and would not be accepted by the lumberman. A tree of the same species and size growing in a clump will yield five logs because the shaft does not diminish in size so fast owing to the lighter growth of limbs that form its top. While the larger spruces are found scattered among the hardwoods, the tallest ones of like diameter are found growing in the spruce clumps."

years on the stump). The tree measured 28 inches in diameter and 97 feet in height, and a merchantable log 65 feet in length was cut from it. The central stem measured 200 cubic feet (from 1,200 to 1,500 board feet). When cut it was in thrifty growing condition with a long, full crown. The trunk was sound throughout except for a slight discoloration and softness in the sapwood near the top. The late Chas. H. Green, of White River Junction, Vt., gave the following details of a tree cut in Pittsfield, Vt., at an elevation of about 800 feet above the White River. The tree was cut into four 14-foot logs and a top log of 24 feet. The top diameter of the fifth log was 22 inches and the top diameter of the butt log 36 inches. The total scale was 3,590 feet. The tree was upward of 320 years old on the stump and was broken off at a height of 120 feet, where it had a diameter of 5 inches. A companion tree of 30 inches on the stump made six 14-foot logs, the last of which was 12 inches at the top end. He stated that when the logs reached the bank it was decided to blast them open in order to run them in a small stream and that when they reached the Connecticut River the rivermen used them as boats while poling logs out of the eddies.

SUSCEPTIBILITY TO INJURY.

FIRE.

Spruce is particularly susceptible to injury by fire on account of its slow growth in early life, the resinous character of its exudations, and its shallow root system. Ground fires are a menace to young spruce for a much longer period than to many of its associates. Its slow growth delays the formation of a protective corky layer of bark; and the long persistence of its lower branches lays it open to complete destruction by fires which its less tolerant neighbors would escape by having their crowns sufficiently elevated to be out of reach of serious damage.

On many of the situations where spruce grows the soil is very shallow. It is here dependent in large measure upon the humus and moss cover for the protection of its superficial root system. A surface or ground fire in such a place would almost certainly destroy this protective layer, even though it was not of sufficient intensity to scorch the trunks of the trees. Serious damage to the roots would almost inevitably result, thus causing the death of the stand outright or creating a condition favorable to windthrow.

On account of the tolerance and consequently the relatively heavy crown of spruce, a large quantity of inflammable debris is left on the ground after lumbering, which makes the fire menace much greater in spruce stands than in those of the pine and other species in the region of its occurrence. This menace persists for several years, probably not less than from 7 to 10 years, even when the tops are lopped. Lopped tops in contact with the ground will have commenced to

decay by that time. There are so many twigs or lops, however, that they must be piled out of the way of logging, and thus elevated from the ground they remain in an inflammable condition for a long time. Windrows of spruce lops even under fairly moist conditions will support the weight of a man, thus showing them to be in comparatively sound condition, at least from 7 to 10 years after cutting. Even if they could be scattered over the ground, their bowed form and elasticity would render it difficult to secure an intimate contact with the ground unless they were cut up into small pieces. Their rapid decay is still further hindered by the resinous character of the wood.

FROST.

Spruce is rather generally subject to splitting, particularly in very cold exposed situations. This defect is caused by an unequal shrinkage between the heart and sapwood under the action of a sudden drop in temperature below freezing. It may also be accentuated to some extent by the swaying of the tree in the wind when in a frozen condition. Spruce having this defect is known among lumbermen as "seamy" spruce. If the grain of the wood is straight, the defect will not cause much loss in sawing; but if it is not straight, the tree is useless except for pulp. As frost crack results from climatic conditions, its prevention is not feasible. Spruce is not particularly susceptible to the defect known as "cup or ring shake."

SUN.

Trees grown in a dense forest usually have their boles well cleared of branches. Therefore when a portion of the stand is removed injury may result from sun scald through exposure of the remaining trees to direct insolation. The damage is generally confined to the side of the tree facing the southeast, and conditions are most favorable to its occurrence in the late winter and early spring. It may result from the cambium on that side of the tree becoming prematurely active under the influence of a period of mild weather and a heavy freeze coming on afterwards and killing the new growth. A thawing of one part of the tree under the influence of direct insolation while the rest remains frozen might also cause it. Separation of bark and wood and the collection of moisture in the cavity almost inevitably follow such thawing and afford suitable opportunitie for the entrance and development of fungous spores. Such a condition gives rise to a defect known as "spruce canker."

INUNDATION AND ICE GIRDLING.

Although spruce will grow and thrive in moist situations, it is permanently injured if not killed outright by inundation, depending upon the duration of the flooding. Spruce is also killed by girdling¹ when the inundation is accompanied by the formation of ice about the tree trunks.

¹ See D. 57. Bulletin 26. U. S. Department of Agriculture, Division of Forestry, Oct. 1899.

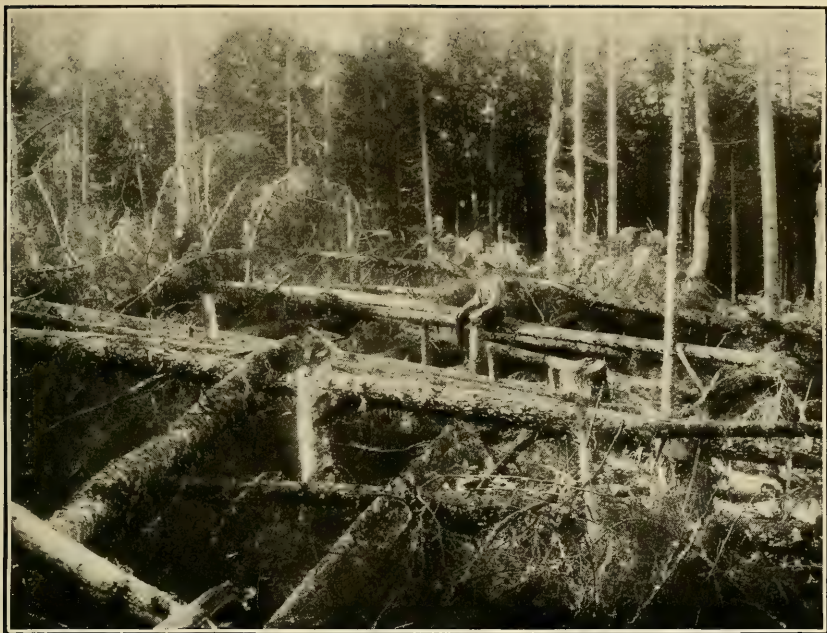


FIG. 1.—WINDFALL AFTER LOGGING.



FIG. 2.—STAND KILLED BY FIRE WHICH DESTROYED THE THIN SOIL COVER OF MOSS,
EXPOSING THE ROOTS WHICH REST ON THE UNDERLYING ROCK STRATA.

DAMAGE TO SPRUCE.

ANIMALS.

Young spruce may be severely damaged by the tearing off of its bark by deer when rubbing their antlers to remove the "velvet." Balsam, however, is much more liable to injury of this sort than is spruce, presumably because of its smoother bark and the healing effect of its resin. Hedgehogs also damage spruce to some extent by gnawing the bark. Squirrels and mice eat enormous quantities of seed, and undoubtedly do further damage by burrowing about the roots, thus exposing them to danger of fungous infection. The rodents may even be the means themselves of inoculation. Squirrels, particularly, feed on the fruiting bodies of different fungi, which can often be found on dead limbs along the trunk of spruce where they have been carried and partly eaten.

GRAZING.

Spruce is susceptible to very little injury by the browsing either of deer or domestic animals. When very young the seedlings are liable to serious injury by being trampled by the grazing stock. If it were not for this, the presence of stock in young spruce stands would be of advantage in keeping the grass cropped down and the young hardwoods and balsam browsed.

There is at the present time a tendency in parts of the spruce regions of New Hampshire and Vermont to allow pasture land to grow up to spruce, at the same time allowing stock to graze as long as they can find sufficient pasturage. Such an attempted dual use of the land is of advantage to neither the cattle grazed nor to the forests to be grown. The resulting stand of spruce is very ragged and uneven-aged, being composed of large, spreading-crowned, scrubby trees interspersed by occasional thickets of younger growth. These latter come up in the openings which are from time to time cut off from grazing by the interlacing of the low crowns of the larger trees, which hinders the passage of the stock. On account of the gradual encroachment on the intervening areas of the crowns of the larger trees, many of these younger saplings are eventually suppressed.

The yield from such a stand is very much less than the land is capable of producing; the quality of the material is inferior, and much of it is useless even for pulp. Much time also is wasted in cutting the big-limbed, scrawny trees, which materially reduce the output per day, increase the cost, and yield heavy sticks difficult to handle. Thus the normal value of the land is reduced not only as a pasturage investment but as an investment for pulpwood production.

WIND AND SNOW.

The susceptibility of spruce to damage by windthrow is very great on certain situations on account of the shallow nature of its root system. The foliage and young shoots may be considerably damaged by hail and are thus rendered more vulnerable to insect

and fungous attacks. Wet snow and sleet are also responsible for considerable damage to young spruce. The weight of snow will often bend the young trees over beyond the point where they can recover their erect position.

FUNGOUS GROWTH.¹

Spruce is susceptible to injury by fungous growths of many sorts, which gain entrance into the wood through wounds resulting from a variety of causes. Some of the fungi can not thrive on a thrifty growing tree, but are secondary causes of death. Others, however, are unselective as to the thrift of their host.

Three root parasites² which attack the spruce are *Polyporus schweinitzii*, *Poria* (*Polyporus*) *subacida*, and *Fomes* (*Polyporus*) *annosus*. *Polyporus schweinitzii*, the worst of these, is very prevalent throughout the northern spruce and fir forests, where it attacks old and young trees alike, as does also *Poria subacida*. To what extent *Poria subacida* is the cause of the death of the tree, however, is not known, nor whether it attacks perfectly healthy trees; but it is known to be particularly destructive to dead timber. *Fomes annosus*, although very destructive in the forests of Europe, has not been accounted so in our eastern forests up to the present. These fungi usually spread through the soil and gain entrance to the tree through the roots, which makes them difficult to detect and still more difficult to combat. While it will not do to hunt out diseased trees as is done in Europe, it may prove of advantage whenever an infected group of trees is found in lumbering to cut all nearby trees. Decay will not, in many cases, have extended so far up the trunk as to prevent one or two merchantable logs being obtained.

Three wound parasites² which do a great deal of damage to spruce are *Trametes pini abietis*, *Fomes* (*Polyporus*) *pinicola*, and *Polyporus sulphureus*. They gain entrance to the tree above ground through wounds on the trunk and branches, and spread up and down the trunk from the point of infection to the topmost branches and to the roots. *Trametes pini abietis* very commonly attacks both the heartwood and sapwood of spruce and literally riddles them with small holes. *Fomes pinicola*, while it attacks living trees, is generally found on those individuals which have a weakened vitality, and is one of the first to settle on such trees as have met death through other causes. *Polyporus sulphureus* is found on spruce, but is more prevalent on hardwoods. There are undoubtedly many others of

¹ Those desiring detailed information concerning fungous diseases and how to combat them should communicate with the Division of Forest Pathology, Bureau of Plant Industry, Washington, D. C.

² Von Schrenck, Hermann: "Some Diseases of New England Conifers," U. S. Department of Agriculture, Div. of Veg. Phys. and Path., Bulletin 25, 1900.

this type of fungous growth which prey upon the spruce, but those enumerated are the most common and most destructive.

It is obviously impossible to introduce intensive protective measures in our wild and uncultivated forests. However, it is possible, and in the long run it will be profitable, to adopt such measures as will certainly aid in prolonging their health and usefulness. In the process of lumbering, particularly where the selection system is being employed, a careful scrutiny should be made of all trees which are to be left. Merchantable trees in a defective condition, whatever their size, should be removed in order to get the present value of their sound portions and at the same time prevent so far as possible their becoming a menace to the healthy trees remaining. This would include the cutting of standing dead and down timber when marketable. In similar manner, areas upon which the timber has been killed by fire, windfall, or serious insect attacks, should be lumbered immediately upon the discovery of the damage. If such timber is cut immediately, its value will be only slightly, if at all impaired, and it will yield as good lumber as before its death. This logging will, in certain instances, entail a somewhat greater expense. The disposal of slash by burning after lumbering, using suitable safeguards, is another precaution which will be found desirable. If slash is allowed to remain on the ground, it constitutes a center of infection for fungous diseases and insect pests, thus jeopardizing the health of the remaining timber.

INSECTS.¹

Spruce has many insect enemies which prey upon its bark, wood, twigs, and foliage. Those known as bark and wood miners cause the greatest damage. They attack the old and valuable timber and are either primary or secondary causes of its death. Young trees are subject to injury by the white-pine weevil (*Pissodes strobi* Peck) and the spruce gall louse (*Chermes* sp.). The latter affects the young twigs and the former the terminal shoots. As a result of their work the trees become deformed or stunted in growth.

Among the bark miners the southern pine beetle (*Dendroctonus frontalis* Zimm.) and the eastern spruce beetle (*Dendroctonus piceaperda* Hopk.) are considered the most serious pests. To the former has been attributed the destruction of a vast amount of spruce timber in West Virginia and the adjacent region, while the eastern spruce beetle is accounted responsible for the ravages of past years in Maine and New Hampshire. The attacks of the southern pine beetle are disastrous to both pine and spruce in areas south of Penn-

¹Those desiring detailed information concerning forest insect pests and methods of combating them should communicate with the Division of Forest Insect Investigations, Bureau of Entomology, Washington, D. C.

sylvania; but thus far the eastern spruce beetle is credited with confining its baleful activity to the spruce alone and to areas north of West Virginia. Both of these insects attack perfectly sound, thrifty timber of the best quality—that is, trees from 10 to 12 inches in diameter and larger. Although they manifest a preference for standing trees, they will breed in windfallen trees and, more rarely, in stumps and logs.

Certain insects which infest the spruce are able to do their work only when the vitality of the tree has been reduced either by a former insect attack or through disease. The wood miners work within the woody parts of the tree rather than in the cambium, and continue their work after its death, as well as in the log after it is cut. They are usually of no detriment to the health of the living tree, but their excavations into both the heartwood and sapwood cause wormhole defects and afford favorable means for the entrance of fungi.

While the insect enemies of spruce have many natural enemies, such as the birds, parasitic insects, and fungi, and predacious insects which feed on and destroy their young, their ravages are not always held in check by such means. According to Dr. A. D. Hopkins,¹ forest entomologist of the U. S. Bureau of Entomology, the general methods to be adopted are as follows:

For the southern pine beetle: (1) remove and burn the infested bark from the trunks of the trees while still standing; (2) place the infested portions of the trunks in water; or convert the infested trees into cordwood, lumber, or other products and burn the slabs or bark before the beetles leave the bark.

For the eastern spruce beetle: (1) Regulate the winter cutting so as to include as many of the infested, dying, and dead trees as possible, and place the logs from them in water before the first of June; (2) regulate the summer cutting so that as many recently attacked trees as possible may be cut and the bark removed from the trunks and stumps; (3) girdle, early in June, a large number of trees, in the vicinity of infested localities where logging operations are to be carried on the following summer and winter, the girdled trees to be felled and the logs containing the broods of the insect attracted to them either peeled or placed in water before the first of the succeeding June. The trees selected to be girdled should be sound and healthy and not less than 15 inches in diameter, and the girdling should be done by hacking the tree with an ax through the bark into the sapwood and around the trunk 2 or 3 feet above the base.

A large percentage of dead spruce remains sound for a considerable period after being killed by these insects, and should be salvaged when

¹ U. S. Department of Agriculture, Div. Ent. Bulletin 28; also U. S. Department of Agriculture Farmers' Bulletin 476.

possible. Since the mature living timber is the most subject to attack, the cutting over of the remaining virgin tracts, using an approximate diameter limit of 14 inches at breast height, will greatly reduce the danger of subsequent serious damage arising from this source.

GROWTH.

Spruce varies more or less widely in growth, form, and development with the character of the stand, the density of the stocking, and the exposure and quality of the soil. Virgin or old-growth stands present a distinctly different set of conditions from the second-growth stands.

The virgin stands are, without exception, of the natural selection form, in which each tree or small group of trees develops individually; all ages and sizes are represented, from seedlings to overmature veterans, but the older age classes generally predominate. The second-growth stands, on the other hand, are in a large measure of even-aged form, either in groups or over whole areas; the trees all start at approximately the same time and develop as a unit rather than as distinct individuals. The conditions surrounding these two modes of development give rise to differences not only in the rate of growth in volume, height, and diameter, but in the form of bole of the individual tree.

HEIGHT GROWTH.

In the virgin forest or in one managed under the selection system, the height growth of spruce bears no definite relation to its age. It is the soil quality, or site quality, whose influence is particularly manifested in height growth. Mature spruce in the virgin-forest types in which it characteristically occurs shows the same relative height development in Maine and the Adirondacks for the corresponding soil types. The "spruce swamp" shows the least development in height, averaging for the tallest trees about 60 feet in Maine and 72 in the Adirondacks, followed by the "spruce flats" and "spruce slopes," on which the heights are nearly the same, namely, 70 feet in Maine and 75 feet in the Adirondacks. Spruce reaches its best development on the "spruce and hardwood lands," with heights of 75 feet for Maine and 80 feet for the Adirondacks. The differences in average height for similar types in Maine and the Adirondacks are in large measure accounted for by the fact that the averages for the Adirondacks include a large percentage of virgin growth, while those for Maine are based almost entirely on figures from cull forests, which are lacking in the larger sizes. The inferior height growth in the "spruce swamp" and "spruce slope" situations is attributed to the fact that not only the growth in these situations is slower, but also that the timber in many cases is second growth. Stands in these situations are particularly likely to be overturned by the wind on attaining a certain

height. The succeeding second growth may pass through the same stages, so that these stands may be relatively young.

Table 4 gives height growth of selection stands in Maine, New Hampshire, the Adirondacks, and West Virginia. It will be noted that the heights in New Hampshire are below those in Maine and New York, particularly in the larger diameters. This is undoubtedly due to the fact that the New Hampshire data were collected toward the southern edge of the White Mountain spruce forests, where the prevailing conditions are less favorable to spruce than those farther north. The values given for New York, on the other hand, are doubtless somewhat high because of the exclusive use of dominant trees as a basis for the height curve. The average height development is slightly better in New Hampshire than in Maine and is somewhat better in Maine than in New York for the same type or site.

TABLE 4.—*Height growth of spruce (based on diameter).*

[CURVED.]

Diameter breast high.	Maine. ¹		New Hampshire. ²		New York. ³		West Virginia. ⁴	
	Height.	Basis.	Height.	Basis.	Height.	Basis.	Height.	Basis.
<i>Inches.</i>	<i>Feet.</i>	<i>Trees.</i>	<i>Feet.</i>	<i>Trees.</i>	<i>Feet.</i>	<i>Trees.</i>	<i>Feet.</i>	<i>Trees.</i>
1.....	12		11		11		10	
2.....	18		17		17		16	
3.....	24		23		23		22	
4.....	29	5	29		29		28	
5.....	34	3	34		34	1	34	1
6.....	38	6	38	21	39	6	40	3
7.....	42	8	43	36	43	8	46	1
8.....	46	13	46	76	47	24	51	5
9.....	50	17	50	75	50	19	56	12
10.....	53	31	53	87	53	55	61	26
11.....	56	21	56	76	56	37	66	34
12.....	59	23	53	87	53	29	71	42
13.....	62	19	61	54	60	18	75	36
14.....	65	24	63	63	62	23	79	46
15.....	67	13	65	33	64	15	82	22
16.....	70	13	67	36	66	5	86	39
17.....	72	13	63	24	63	4	89	20
18.....	74	19	69	21	70	2	92	29
19.....	76	5	71	13	71	1	95	16
20.....	78	7	72	9	73		97	27
21.....	79	5	72	3	74	1	100	18
22.....	81	4	73	3	76	1	102	21
23.....	83	4	74				104	13
24.....	84	1	74				105	8
25.....	86	1	75				107	9
26.....	87		75	3			109	7
27.....							110	6
28.....							111	9
29.....							112	6
30.....							113	2
31.....							114	2
32.....							115	
33.....							116	1
34.....							117	1
		260		725		250		462

¹ Spruce slope type. Data collected by R. S. Hosmer.² Spruce slope type. Data collected by T. S. Woolsey, jr.³ Spruce hardwood type (dominant trees only). From data collected by the Conservation Commission of New York.⁴ Spruce slope type. Data collected by John Foley.

In the even-aged, second-growth forests, the individual tree is not subjected to long or varied periods of suppression. All of the trees

which gain positions in the main crown cover start at about the same time and develop with very little interruption. Their height and age may consequently be easily correlated. The following table shows the average height of the dominant and intermediate trees comprising even-aged second-growth spruce stands of different ages and on sites of different quality, measured in Maine, New Hampshire, and Vermont in the fall of 1910.

TABLE 5.—*Height growth of spruce in even-aged, old pasture stands in Maine, New Hampshire, and Vermont according to age and site qualities.*

[Average height of all dominant (including codominant) and intermediate trees in stands of different ages.]

[CURVED.]

Age.	Site qualities.			Basis.
	I.	II.	III.	
<i>Years.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Sample plots.</i>
20.....	24	19	14	.....
25.....	31	25	20	1
30.....	36	31	25	.....
35.....	42	36	30	1
40.....	46	40	34	.....
45.....	51	44	37	1
50.....	55	47	40	6
55.....	58	50	42	6
60.....	61	53	45	8
65.....	64	55	47	16
70.....	66	57	49	14
75.....	68	59	50	4
80.....	70	61	52	1
85.....	72	63	53	.....
90.....	73	64	55	.....
95.....	74	65	56	1
100.....	76	66	57	.....
				59

From sample plot data collected in 1910.

For purposes of comparison the growth in height of Norway spruce is given in Table 6.

TABLE 6.—*Height growth of Norway spruce.*¹

Age.	Average height of stand.
<i>Years.</i>	<i>Feet.</i>
5	8
10	16
15	24
20	32
25	39
30	45
35	50
40	54
45	58
50	61
55	64
60	66

¹ Based on all measurements of all trees in 11 plantations (8 Quality I and 3 Quality II) 24-55 years old (curved), made by Messrs. Tillotson, Barrows, and Williamson, of the Forest Service, in 1911, in Rhode Island, Connecticut, Illinois, and Iowa.

There is little doubt that Norway spruce makes a better height growth in early life than our native spruce. It is well to remember, however, in making comparisons in this particular instance, that the two grow under entirely different sets of conditions. While the native spruce has developed from seed under the keenest possible competitive conditions, the Norway stock was in all likelihood nursery grown, so spaced when planted as to eliminate undesirable competition during early life, and possibly even cultivated. Then, too, such plantations in general have been made on a rather better soil even than that on which the average first quality red spruce stands are found.

A comparison of the height growth of spruce seedlings in the forest and in the open is shown in Table 7.

TABLE 7.—*Height growth of spruce seedlings.*

Age.	Height.	
	In the forest. ¹	In the open. ²
<i>Years.</i>	<i>Feet.</i>	<i>Feet.</i>
5	0.3	0.8
10	0.7	2.4
15	1.1	6.0
20	1.5	10.0
25	2.0	16.0
30	2.6	28.0
35	3.3	35.0
40	4.1	-----
45	5.0	-----

¹ Based on 615 trees. Data collected by R. S. Hosmer, 1901, on the New York State Forest Reserve.

² From p. 59, "Forest Conditions of Northern New Hampshire," Bulletin 55, Bureau of Forestry, U. S. Dept. of Agriculture.

The column of height in the open is entirely conservative, as will be noted by comparing it with Table 5.

DIAMETER GROWTH.

The growth in diameter of spruce in virgin and other selection-form forests is, like the height, largely independent of age. The relation between diameter and age, however, can more readily be established than that between height and age, since merely from a stump analysis results closely approximating the truth can be obtained.

TABLE 8.—*Diameter and age of spruce in Maine.*¹

[(a) Averaged according to age.]

Class.	Number of trees.	Per cent of total number.	Average age.	Average butt diameter.	Average length.	Average top diameter.
				<i>Inches.</i>	<i>Feet.</i>	<i>Inches.</i>
Under 125 years.....	52	4.9	114.5	11.5	26.4	8.0
125-150 years.....	120	11.4	138.7	12.1	28.5	8.5
150-175 years.....	210	20.0	162.6	12.9	29.9	8.6
175-200 years.....	218	20.8	182.6	13.5	30.3	8.9
200-225 years.....	210	20.0	210.8	15.0	31.3	9.9
225-250 years.....	125	11.9	235.5	15.9	32.2	10.0
250-275 years.....	72	6.9	260.3	16.0	32.9	10.3
275-300 years.....	29	2.8	285.6	17.5	34.4	11.5
Over 300.....	14	1.3	311.6	18.5	37.1	12.0
Average of all ²	1,050	.....	192.0	14.1	30.6	9.2

[(b) Averaged according to butt diameter.]

Class.	Number of trees.	Per cent of total number.	Average age.
Under 10 inches.....	42	4.0	162.0
10-11 inches.....	97	9.2	170.1
11-12 inches.....	123	11.7	171.7
12-13 inches.....	158	15.1	174.0
13-14 inches.....	162	15.3	³ 189.1
14-15 inches.....	117	11.2	³ 185.4
15-16 inches.....	94	9.0	197.7
16-17 inches.....	76	7.3	214.0
17-18 inches.....	62	5.9	217.1
18-19 inches.....	43	4.1	228.7
19-20 inches.....	19	1.8	230.1
Over 20 inches.....	57	5.4	244.8
	1,050	.....	.....

¹ From a special report "On the Growth of Spruce, by Austin Cary, in the Second Annual Report of the Forest Commissioner of the State of Maine, 1894. In explanation of the foregoing table Mr. Cary says: "In all, 1,050 spruce logs were examined for this purpose, taken on drives and mill yards. The length and end diameters of each log were measured, and the rings of the butt counted to ascertain the age. About two-thirds of the logs were grown in the western part of the State on the drainage of the Androscoggin. The remainder were partly from the Kennebec, partly from the Aroostock branches of the Penobscot. A small proportion of the logs measured were cut for pulp, which renders the selection all the more representative. The tables which embody the results of the work need, it would seem, very little explanation. The trees were first divided into age classes, and the dimensions of the logs in each class averaged. Then the same logs were divided according to butt diameters and the average age ascertained for trees of each size. The most usable result of the work is the grand average of these facts for the whole 1,050 logs. The average dimensions of the logs represent a tree containing about 23 cubic feet, or say 120 board feet, and this was grown on the average in 192 years. Adding to the log 2 cubic feet for stump and 7 more for the top, adding also to the age 20 more years for the height growth of the stump, then dividing contents by age gives the figures fifteen-hundredths cubic feet. That is to say, a spruce tree on the average and throughout its life until cut, maintains a growth of 1 cubic foot in six and two-thirds years. In adult life the growth per tree would be considerably greater. In young seedlings it would for many years be less. The percentage of growth to stand can not be immediately derived from these figures."

[In connection with the information just quoted, it seems evident that the words "log" and "tree" are used synonymously in referring to the "used length."—Author.]

² A log of these average dimensions contains 23 cubic feet, or about 120 board feet.

³ A 13 $\frac{1}{2}$ -inch tree, of course, is not as a rule older than a 14 $\frac{1}{2}$ -inch tree. The irregularity shown in the series would doubtless be corrected if the larger number of trees was taken.

Average of 50 pine logs: Age, 102.8; butt diameter, 16.1; length, 30.3; top diameter, 11. A log of these dimensions contains 30 cubic feet, or about 175 board feet.

It is in most cases of little practical value to the lumberman to know the direct relation between the actual age and the diameter of trees in a selection forest. A knowledge of the length of time required for a tree to grow from 1 inch diameter class to the next is, however, important. Tables 9, 10, and 11 show this as well as the corresponding rate of growth per annum of each diameter class.¹

¹ Besides showing these values based on an average of all trees measured, the West Virginia and Adirondack tables show absolute maximum and average maximum values as well. These are obtained by using only values representing maximum and average minimum growth conditions, eliminating all periods which show the effect of suppression.

TABLE 9.—*Diameter growth of spruce in Maine, by types.*¹

[Based on the last 20 years.]

[CURVED.]

Diameter breast high.	Lower spruce and hardwood land, 564 trees.		Upper spruce and hardwood land, 379 trees.		Lower spruce slope, 144 trees.		Upper spruce slope, 87 trees.		Average of all types, 1,174 trees.	
	Periodic annual growth.	Time required to grow 1 inch.	Periodic annual growth.	Time required to grow 1 inch.	Periodic annual growth.	Time required to grow 1 inch.	Periodic annual growth.	Time required to grow 1 inch.	Periodic annual growth.	Time required to grow 1 inch.
Inches.	Inches.	Years.	Inches.	Years.	Inches.	Years.	Inches.	Years.	Inches.	Years.
5.....	0.036	28	0.054	19	0.015	67	0.026	38	0.034	29
6.....	.048	21	.063	16	.022	45	.030	33	.045	22
7.....	.063	16	.071	14	.032	31	.034	29	.056	18
8.....	.080	13	.078	13	.046	22	.038	26	.068	15
9.....	.098	10	.085	12	.067	15	.041	24	.081	12
10.....	.114	9	.091	11	.093	11	.044	23	.093	11
11.....	.126	8	.096	10	.113	9	.047	21	.105	10
12.....	.136	7	.102	10	.124	8	.049	20	.115	9
13.....	.142	7	.109	9	.127	8	.052	19	.122	8
14.....	.146	7	.112	9	.126	8	.055	18	.126	8
15.....	.148	7	.112	9	.122	8	.058	17	.129	8
16.....	.150	7	.109	9	.116	9	.060	17	.130	8
17.....	.148	7	.106	9	.110	9	.062	16	.129	8
18.....	.146	7	.106	9	.103	10	.062	16	.126	8
19.....	.142	7	.106	9	.096	10	.062	16	.122	8
20.....	.138	7	.106	9	.091	11	.060	17	.116	9
Average.....	.141	7	.104	10	.112	9	.052	19	.119	8

¹ From data secured by R. S. Hosmer, 1902, on partially culled land in Squaw Mountain Township, Me., and including trees of all crown classes.

TABLE 10.—*Diameter growth of spruce in New York.*¹

[All types, spruce-hardwood type chiefly; dominant trees only.] [CURVED.]

Diameter breast high.	Absolute maximum.		Average maximum.		Average.		Basis.
	Periodic annual growth.	Time required to grow 1 inch.	Periodic annual growth.	Time required to grow 1 inch.	Periodic annual growth.	Time required to grow 1 inch.	
Inches.	Inches.	Years.	Inches.	Years.	Inches.	Years.	Trees.
2 1.....	0.176	5.7	0.111	9.0	0.046	21.7	.....
2.....	.218	4.6	.140	7.1	.061	16.4	.....
3.....	.253	4.0	.164	6.1	.075	13.3	.....
4.....	.282	3.5	.186	5.4	.089	11.2	.....
5.....	.309	3.2	.205	4.9	.101	9.9	10
6.....	.324	3.1	.217	4.6	.110	9.1	42
7.....	.331	3.0	.223	4.5	.115	8.7	32
8.....	.328	3.0	.223	4.5	.118	8.5	57
9.....	.317	3.2	.219	4.6	.121	8.3	46
10.....	.297	3.4	.210	4.8	.124	8.1	65
11.....	.270	3.7	.197	5.1	.124	8.1	44
12.....	.245	4.1	.184	5.4	.123	8.1	27
13.....	.216	4.6	.168	6.0	.119	8.4	19
14.....	.187	5.3	.150	6.7	.112	8.9	25
15.....	.156	6.4	.128	7.8	.101	9.9	15
16.....	.132	7.6	.110	9.1	.089	11.2	4
17.....	.110	9.1	.093	10.8	.076	13.2	4
18.....	.....	.....	.....	.....	.064	15.6	2
19.....	.....	.....	.....	.....	.051	19.6	1
20.....	.....	.....	.....	.....	.....	.....	.....
							393

¹ From data collected by the Conservation Commission of New York in 1912 on culled land in Essex and Herkimer Counties.

² The time required to grow to a diameter of 1 inch at breastheight was 11 years for "absolute maximum" growth conditions, 17 years for "average maximum," and 35 years for "average."

TABLE 11.—*Diameter growth of spruce (virgin) in West Virginia.*¹

[Spruce slope type.]

[CURVED.]

Diameter breast high.	Absolute maximum.		Average maximum.		Average.		Basis.
	Periodic annual growth.	Time required to grow 1 inch.	Periodic annual growth.	Time required to grow 1 inch.	Periodic annual growth.	Time required to grow 1 inch.	
<i>Inches.</i>	<i>Inches.</i>	<i>Years.</i>	<i>Inches.</i>	<i>Years.</i>	<i>Inches.</i>	<i>Years.</i>	<i>Trees.</i>
2 1.....	0.202	5.0	0.126	7.9	0.051	19.6	-----
2.....	.220	4.5	.138	7.2	.056	17.9	-----
3.....	.235	4.3	.148	6.8	.060	16.7	-----
4.....	.250	4.0	.157	6.4	.064	15.6	-----
5.....	.262	3.8	.166	6.0	.069	14.5	1
6.....	.274	3.6	.174	5.7	.074	13.5	3
7.....	.284	3.5	.182	5.5	.079	12.7	1
8.....	.291	3.4	.188	5.3	.084	11.9	5
9.....	.296	3.4	.193	5.2	.090	11.1	12
10.....	.300	3.3	.198	5.1	.095	10.4	24
11.....	.300	3.3	.201	5.0	.102	9.8	27
12.....	.300	3.3	.203	4.9	.106	9.4	37
13.....	.298	3.4	.204	4.9	.109	9.2	28
14.....	.294	3.4	.202	5.0	.110	9.1	42
15.....	.290	3.4	.200	5.0	.111	9.0	19
16.....	.282	3.5	.196	5.1	.110	9.1	33
17.....	.275	3.6	.192	5.2	.108	9.3	13
18.....	.265	3.8	.186	5.4	.106	9.4	17
19.....	.254	3.9	.178	5.6	.103	9.7	8
20.....	.243	4.1	.172	5.8	.100	10.0	20
							290

¹ From data collected by John Foley in 1903 in Greenbrier County and including trees in all crown classes.² The time required to grow to a diameter of 1 inch at breastheight was 7 years for "absolute maximum" growth conditions, 11 years for "average maximum," and 26 years for "average."

Diameters in even-aged stands vary directly with the age of the stand, so that the relationship of one of the other is of considerable importance. This relationship is brought out in Table 12, which is based on the average diameter growth of the dominant (including codominant) and intermediate trees.

TABLE 12.—*Diameter growth of red spruce in even-aged, old pasture stands in Maine, New Hampshire, and Vermont, according to age and site qualities.*[Average diameter breast high ¹ of all dominant (including codominant) and intermediate trees in stands of different ages.]

Age.	Site qualities.			Basis.
	I.	II.	III.	
<i>Years.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sample plots.</i>
20.....	3.8	3.1	2.4	-----
25.....	4.9	4.0	3.2	1
30.....	5.9	4.9	3.9	-----
35.....	6.8	5.7	4.6	1
40.....	7.5	6.3	5.2	-----
45.....	8.1	6.9	5.7	1
50.....	8.6	7.4	6.1	6
55.....	9.0	7.7	6.4	6
60.....	9.3	8.0	6.7	8
65.....	9.5	8.2	7.0	16
70.....	9.7	8.5	7.2	14
75.....	9.9	8.7	7.4	4
80.....	10.1	8.9	7.6	1
85.....	10.2	9.0	7.8	-----
90.....	10.4	9.2	8.0	-----
95.....	10.6	9.4	8.2	1
100.....	10.8	9.5	8.4	-----
				59

¹ From sample plot data collected in 1910.

For purposes of comparison Table 13, giving diameter growth of Norway spruce (*Picea excelsa*) is included.

TABLE 13.—*Diameter growth of Norway spruce.*¹

[CURVED.]

Age.	Average diameter breast high of stand.
<i>Years.</i>	<i>Inches.</i>
5	1.0
10	2.8
15	4.4
20	5.7
25	6.8
30	7.7
35	8.4
40	9.0
45	9.6
50	10.2
55	10.8
60	11.4

¹ Based on the measurement of all trees in 11 plantations (8 Qualities I and 3 Quality II) 24–55 years old, made by Messrs. Tillotson, Barrows, and Williamson in 1911, in Rhode Island, Connecticut, Illinois, and Iowa.

Even more than with height comparisons it is necessary to bear in mind the influence of soil, spacing, and cultural methods on the diameter growth of volunteer stands and plantations when drawing conclusions from the foregoing figures as to the relative growing qualities of red and Norway spruce.

SECTIONAL AREA GROWTH.

The growth in sectional area, or the increase in the superficial area of a given cross section, is effective as a means of comparison for even-aged stands of different ages or of the same age but of different site qualities. Either the total basal area of the stand at a definite height from the ground, usually at breastheight, or the basal area of the average tree, may be employed. Table 14, covering second-growth, even-aged spruce stands of the old pasture type shows the relative average total basal area of stands of different ages and site quality based (1) on all green trees; (2) on green trees 6 inches and over; (3) on all dominant trees; and (4) on all dominant and intermediate trees.

TABLE 14.—*Breast-high sectional area growth of red spruce in even-aged, old pasture stands in Maine, New Hampshire, and Vermont, according to age and site qualities.*

QUALITY I.

[CURVED.]

Age.	All green trees.			Green trees 6 inches and over.			Dominant and intermediate trees.			Dominant trees only.		
	Trees per acre.	Basal area.	Average diameter breast high.	Trees per acre.	Basal area.	Average diameter breast high.	Trees per acre.	Basal area.	Average diameter breast high.	Trees per acre.	Basal area.	Average diameter breast high.
Years.	No.	Sq. ft.	Inches.	No.	Sq. ft.	Inches.	No.	Sq. ft.	Inches.	No.	Sq. ft.	Inches.
20	1,589	115	3.6				1,294	102	3.8	489	54	4.5
25	1,295	142	4.5	102	20	6.0	1,076	140	4.9	466	80	5.6
30	1,110	168	5.3	187	47	6.7	887	169	5.9	447	106	6.6
35	989	193	6.0	267	77	7.3	756	190	6.8	432	129	7.4
40	882	216	6.7	345	114	7.8	668	205	7.5	420	150	8.1
45	898	237	7.3	419	157	8.3	603	216	8.1	410	167	8.7
50	752	256	7.9	462	195	8.8	558	225	8.6	402	183	9.1
55	707	272	8.4	480	222	9.2	527	232	9.0	395	195	9.5
60	668	286	8.8	487	241	9.5	506	238	9.3	388	206	9.9
65	640	298	9.2	490	256	9.8	490	242	9.5	383	215	10.2
70	620	308	9.5	491	268	10.0	478	247	9.7	378	223	10.4
75	603	317	9.8	490	278	10.2	467	250	9.9	373	230	10.7
80	590	325	10.1	489	287	10.4	457	253	10.1	368	236	10.8
85	579	332	10.3	487	294	10.5	447	256	10.2	363	240	11.0
90	568	338	10.5	485	301	10.7	437	259	10.4	359	245	11.2
95	558	344	10.7	483	308	10.8	427	262	10.6	355	249	11.3
100	549	349	10.8	481	313	10.9	417	264	10.8	351	252	11.5

QUALITY II.

20	1,996	98	3.0				1,603	84	3.1	566	40	3.6
25	1,520	120	3.8				1,316	115	4.0	530	60	4.6
30	1,285	142	4.5				1,062	139	4.9	504	81	5.4
35	1,142	162	5.1	260	58	6.4	890	157	5.7	484	101	6.2
40	1,032	182	5.7	335	88	7.0	774	171	6.3	470	119	6.8
45	949	199	6.2	403	122	7.4	697	181	6.9	459	136	7.4
50	880	215	6.7	467	155	7.8	643	189	7.4	451	151	7.8
55	830	229	7.1	497	180	8.1	605	196	7.7	443	162	8.2
60	789	242	7.5	516	199	8.4	575	201	8.0	435	172	8.5
65	756	253	7.8	530	214	8.6	551	206	8.2	427	181	8.8
70	732	262	8.1	540	226	8.8	532	210	8.5	420	188	9.1
75	708	270	8.4	544	235	8.9	516	213	8.7	413	194	9.3
80	689	278	8.6	544	244	9.1	503	216	8.9	407	200	9.5
85	672	284	8.8	542	251	9.2	492	220	9.0	401	205	9.7
90	656	290	9.0	540	257	9.3	482	223	9.2	395	209	9.8
95	642	295	9.2	537	263	9.5	472	226	9.4	390	213	10.0
100	632	300	9.3	533	268	9.6	463	228	9.5	385	217	10.2

QUALITY III.

20	2,803	81	2.3				2,134	67	2.4	678	27	2.7
25	1,870	98	3.1				1,620	90	3.2	623	42	3.5
30	1,540	115	3.7				1,304	109	3.9	580	57	4.3
35	1,357	131	4.2				1,074	124	4.6	548	73	5.0
40	1,224	147	4.7	311	61	6.0	924	136	5.2	526	90	5.6
45	1,129	161	5.1	386	89	6.5	827	145	5.7	514	105	6.1
50	1,055	175	5.5	455	115	6.8	755	153	6.1	505	119	6.5
55	996	187	5.9	515	138	7.0	703	159	6.4	496	129	6.9
60	945	198	6.2	549	156	7.2	664	164	6.7	488	138	7.2
65	903	208	6.5	572	171	7.4	634	168	7.0	480	146	7.5
70	866	216	6.7	587	183	7.6	609	172	7.2	472	153	7.7
75	838	224	7.0	597	193	7.7	588	176	7.4	464	158	7.9
80	813	230	7.2	606	201	7.8	569	180	7.6	457	164	8.1
85	790	236	7.4	602	207	8.0	551	183	7.8	450	168	8.3
90	772	242	7.6	596	212	8.1	533	186	8.0	443	173	8.5
95	760	246	7.7	588	217	8.2	516	189	8.2	436	177	8.6
100	750	251	7.8	580	222	8.3	499	192	8.4	430	181	8.8

Based on 59 sample plots, measured in 1910. Total area, 13.1 acres.

VOLUME GROWTH.

The increase in volume of trees growing in the virgin, or selection, forest is seldom considered on the basis of age for reasons already discussed under height and diameter growth. We are not much interested, for the present at least, in knowing how long it took, or would take again, to produce a spruce of a certain size under similar virgin forest conditions. Most lumbermen are desirous of knowing what can be expected of trees of given sizes for the immediate future. The conditions under which such growth is likely to take place will vary widely, so widely in fact that general tables of growth would be of little value. A local table made up to fit the special conditions of each case is much preferable. Such a table is readily prepared from volume or taper tables and the general data already presented.

In preparing a table of this kind it is usually assumed that a tree now 10 inches in diameter at breastheight will, when it has grown to a diameter of 11 inches, have the volume of the 11-inch trees with which it is at present associated. Diameter growth figures thus form the basis of the calculations. If the future growth of a virgin stand is to be forecasted, the diameter growth figures employed must be those derived from trees growing under these average conditions. Usually, however, an immediate partial cutting is contemplated. Whether the growth figures for the "average maximum" or "absolute maximum" should be used will depend upon the extent to which the cutting opens up the stand. Conditions would need to be exceedingly favorable to warrant using the "absolute maximum" figures of diameter growth. It might even happen that the "average maximum" would show too high results, particularly for forecasting results within the succeeding decade. Spruce does not respond immediately to an opening up of the crown cover. Intermediate trees of from 6 to 10 inches in diameter may not respond at all inside of 12 or 15 years.

The following example will suffice to show how these data are combined:

Suppose one desires to ascertain the probable volume of the 14-inch trees in an average stand of spruce in New York 15 years after a cutting to a 16-inch diameter limit. Assuming such a sized tree to be able to take full advantage of growth conditions and develop at the full "average maximum" rate, the annual increment in diameter would be, according to Table 10, 0.150 inch. In 15 years, consequently, it would have added 2.25 inches to its diameter and become a 16.25-inch tree. The average 14-inch tree, according to Table 4, is 62 feet tall and has a volume according to Table 9 of

136¹ board feet. A 16.25-inch tree similarly is 66 feet tall and has a volume (interpolated) of 188 board feet. Thus the increased growth during the 15 years is 52 board feet, equivalent to 38 per cent. When the future yield of whole stands is to be computed a tabular arrangement of such values will be found convenient.²

Inch diameter class.	Corre- sponding height.	Corresponding volume.		Diameter.			Corresponding volume value from (4). ¹		
		Direct from volume table.	Values in (3) curved.	10 years hence.	20 years hence.	30 years hence.	10 years hence.	20 years hence.	30 years hence.
1	2	3	4	5	6	7	8	9	10
	<i>Feet.</i>	<i>Board ft.</i>	<i>Board ft.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Board ft.</i>	<i>Board ft.</i>	<i>Board ft.</i>
8	47	34	31	10.2	12.5	14.7	61	107	162
9	50	43	43	11.2	13.4	15.6	77	128	188
10	53	55	58	12.1	14.2	16.3	97	148	209
11	56	82	75	13.0	14.9	16.9	118	167	227
12	58	97	95	13.8	15.7	17.5	138	191	245
13	60	120	118	14.7	16.4	18.0	162	212	260
14	62	130	143	15.5	17.0	18.5	185	230	278
15	64	150	170	16.3	17.6	18.8	209	248	288
16	66	200	200	17.1	18.2	19.3	233	267	306
17	68	230	230	17.9	18.9	19.8	257	291	324
18	70	260	260						
19	71	290	295						
20	73	320	331						

¹ Interpolated.

It will be noted that in column 3 the values have not been interpolated, although they might well have been. Instead they have been read directly from the volume table and the irregularities evened off in column 4 by curving. The values in columns 8, 9, and 10 are interpolated from column 4 in order to eliminate the irregularity that would otherwise result from rounding off the diameter values in columns 5, 6, and 7 and reading direct from column 4. Curving of the values in 8, 9, and 10 may in some instances be necessary.

The figures contained in Tables 15 and 16 show the comparative development of spruce in the Adirondacks and West Virginia under "average maximum" growth conditions. Unfortunately, the data were insufficient upon which to extend the New York table above 120 years. An inspection of the height and diameter tables upon which this is based, however, shows the growth of each very much slackened. Inspection of Table 15 itself shows that the periodic annual growth culminated in the ninetieth year, while the mean annual would unquestionably culminate under 150 years. In West Virginia, on the other hand, the periodic annual growth does not begin to slacken until the one hundred and fiftieth year, while the mean annual growth continues unabated until the two hundred and fiftieth year.

¹ Under ordinary circumstances it would be sufficiently accurate to use the value corresponding to a 14-inch tree 60 feet in height which, according to Table 29, is 130 board feet. In computations of this sort however, the volume table values had better be interpolated so as to secure a closer reading. Thus, it may be assumed that if a 14-inch tree has a volume of 130 board feet when 60 feet tall and 160 board feet when 70 feet tall, when it is 62 feet tall its volume will be 136 board feet (130 (160-130) by 0.2).

² The tabular form indicates all the steps to be taken in making up such a table of values for red spruce in New York under "average maximum" growth conditions.

TABLE 15.—Cubic volume growth of red spruce in the Adirondacks, N. Y. (For "average maximum" diameter growth conditions.)

[CURVED.]

Age.	Diameter breast high.	Height.	Volume.	Periodic annual growth.	Mean annual growth.
<i>Years.</i>	<i>Inches.</i>	<i>Feet.</i>	<i>Cu. ft.</i>	<i>Cu. ft.</i>	<i>Cu. ft.</i>
10	0.5	8			
20	1.3	13			
30	2.5	20			
40	4.0	29			
50	5.7	37	3.9		0.078
60	7.8	46	8.0	0.41	.133
70	10.0	53	15.0	.70	.214
80	12.0	58	23.0	.80	.288
90	13.8	62	32.0	.90	.356
100	15.2	65	40.0	.80	.400
110	16.3	67	47.0	.70	.427
120	17.3	68	54.0	.70	.450

Dominant trees—spruce hardwood type.

This table is a combination of growth-diameter Table 10, height Table 4, and volume Table 40.

Data collected by the Conservation Commission of New York in 1912 in Essex and Herkimer Counties.

TABLE 16.—Cubic volume growth of red spruce in West Virginia. (For "average maximum" diameter growth conditions.)

[CURVED.]

Age.	Diameter breast high.	Height.	Volume.	Periodic annual growth.	Mean annual growth.
<i>Years.</i>	<i>Inches.</i>	<i>Feet.</i>	<i>Cu. ft.</i>	<i>Cu. ft.</i>	<i>Cu. ft.</i>
10	0.9	10			
20	2.1	17			
30	3.5	25			
40	5.1	34			
50	6.8	41	4.7		0.094
60	8.6	54	10.7	0.60	.178
70	10.5	64	19.0	.83	.271
80	12.5	73	30.0	1.10	.375
90	14.5	81	43.0	1.30	.478
100	16.4	87	60.0	1.70	.600
110	18.2	93	78.0	1.80	.709
120	19.9	97	96.0	1.80	.800
130	21.4	100	115.0	1.90	.885
140	22.8	103	134.0	1.90	.957
150	24.2	106	154.0	2.00	1.027
160	25.4	108	174.0	2.00	1.088
170	26.6	109	193.0	1.90	1.135
180	27.6	111	212.0	1.80	1.178
190	28.6	112	230.0	1.80	1.211
200	29.5	113	247.0	1.70	1.235
210	30.3	114	263.0	1.60	1.252
220	31.0	114	279.0	1.60	1.268
230	31.7	115	293.0	1.40	1.274
240	32.3	116	307.0	1.40	1.279
250	32.9	116	321.0	1.40	1.284
260	33.5	117	334.0	1.30	1.285
270	34.0	117	347.0	1.30	1.285

All trees—spruce slope type.

This table is a combination of growth-diameter Table 11, height Table 4, and volume Table 41.

Data collected by John Foley in 1903 in Greenbrier County.

While similar data are not available for either Maine or New Hampshire, a comparison of the "Lower spruce and hardwood" and even of the "Average-of-all-type" values of Maine (Table 9) with the "Average" values of New York (Table 10) indicates a better average development in Maine than in New York. Adequate figures for New

Hampshire would undoubtedly show somewhat better general development there than in Maine.

The growth in volume of trees in even-aged stands may be determined in a manner similar to that just described. In this case, however, the diameter growth instead of being calculated by arbitrary periods, such as 10 or 20 years, would be expressed in terms of total age. If the rate of volume growth is to be determined for natural stands undisturbed by thinnings or other treatment which would tend to interfere with the process of elimination by natural competition, the diameter growth should be based on the average growth of all green trees of the even-aged normal stands of different ages. If, however, thinnings are contemplated which will enable the trees composing a stand to grow at their maximum rate with the minimum of competition, the basis for growth should be the mean average of the dominant and intermediate (Table 12) or, under the most favorable conditions, the dominant trees only of the even-aged normal stands of different ages.

STANDS AND YIELDS.

The yield of virgin or selection growth spruce, both present and future, varies widely from one type to the other and within the same type in different regions. It is not possible under the circumstances to discuss the subject in such detail as to cover the full range of conditions which local variations impose, nor are the data available for such discussion. Given certain fundamental data, the range of reliability of which is less restricted than would be yield tables based on the widely variable conditions existing in our present virgin and cull spruce selection forests, the yield for any particular tract can be readily computed.

Aside from that already presented for the various regions under the headings of growth in height, diameter, and volume, the only information needed is the enumeration of the stands¹ the yield of which is to be determined and their average composition as to size and species calculated and tabulated for use in the following convenient form:

Diameter, breast high.	Average number of trees.			Spruce left to grow (average number).
	Spruce.	Other species.	Total.	
1	2	3	4	5
<i>Inches.</i>				

¹ In the appendix (Tables 50-53, inclusive, on pp. 94-97), will be found stand tables prepared from such enumerations in virgin forest growth of the spruce slope type. The associated species are included as a matter of comparison. Incidentally, these tables show in a broad general way the relative production per unit of area of the different regions which they represent. It must not be understood, however, that any claim is made that they show exact average conditions throughout their respective regions.

Having decided whether or not, during the period for which the future yield is to be forecasted, cutting will take place and in what amount, a volume growth table such as that outlined on page 41 would be prepared. If a cutting is contemplated, there should be indicated on the stand table, as column 5, the average number of spruce trees of the different diameters which will be left for future growth. The present yield per acre of the stand would then be determined by multiplying the values in column 2 of the stand table by those in column 4 of the volume growth table. The future yield would similarly be determined by multiplying the values in column 5 of the stand table by those in columns 8, 9, 10, etc., of the growth table.

The yield of second-growth stands may be arrived at in a manner similar to that just outlined. The more direct method, however, is to measure all the trees on sample areas in stands of typical development and known age. The height, diameter, volume, and all other data for each plot are determined separately; and these various data are finally combined into a table on the basis of the age of the trees and the site quality to which they belong. Such a table appears below for normally stocked second-growth stands measured in Maine, New Hampshire, and Vermont. This table is based on data collected in unthinned stands of spruce which have come up on formerly cleared lands. So far as concerns the production of cubic volume and correspondingly, of cordwood volume, these values represent approximately the maximum for their respective ages and site classes. The table is thus suitable for use without modification in predicting the future yields of stands maintained for the production of pulpwood.

TABLE 17.—Yield of red spruce in old-field stands.

[Based on the yield of dominant, codominant, and intermediate trees only.]

QUALITY I.

Age.	Trees per acre.	Basal area.	Average diameter breast high.	Height.	Yield per acre. ¹			Forest form factor.	Basis. ²
Years.	Number.	Sq. ft.	Inches.	Feet.	Bd. ft. ³	Cu. ft. ⁴	Cords. ⁵		Plots.
20	1,294	162	3.8	24					
25	1,076	140	4.9	31					1
30	887	169	5.9	36					
35	756	190	6.8	42					
40	668	205	7.5	46	15,200	3,600	31	.38	
45	603	216	8.1	51	19,700	4,500	40	.42	1
50	558	225	8.6	55	23,300	5,140	48	.42	2
55	527	232	9.0	58	26,200	5,600	55	.42	1
60	506	238	9.3	61	28,500	5,950	60	.41	4
65	490	242	9.5	64	30,500	6,240	64	.40	5
70	478	247	9.7	66	32,100	6,490	68	.40	1
75	467	250	9.9	68	33,500	6,700	70	.39	
80	457	253	10.1	70	34,800	6,890	72	.39	
85	447	256	10.2	72	35,900	7,050	74	.39	
90	437	259	10.4	73	37,000	7,180	76	.38	
95	427	262	10.6	74	38,100	7,300	77	.38	
100	417	264	10.8	76	39,100	7,390	78	.37	
									15

QUALITY II.

20	1,603	84	3.1	19					
25	1,316	115	4.0	25					
30	1,062	139	4.9	31					
35	890	157	5.7	36					1
40	774	171	6.3	40	10,700	3,000	23	.44	
45	697	181	6.9	44	14,100	3,770	31	.47	
50	643	189	7.4	47	17,100	4,320	38	.48	2
55	605	196	7.7	50	19,600	4,720	44	.48	5
60	575	201	8.0	53	21,700	5,050	48	.47	
65	551	206	8.2	55	23,500	5,310	52	.47	9
70	532	210	8.5	57	25,000	5,550	54	.46	8
75	516	213	8.7	59	26,200	5,750	57	.46	3
80	503	216	8.9	61	27,300	5,910	59	.45	
85	492	220	9.0	63	28,300	6,050	61	.44	
90	482	223	9.2	64	29,300	6,170	62	.43	
95	472	226	9.4	65	30,200	6,280	63	.43	
100	463	228	9.5	66	31,100	6,370	64	.42	
									28

QUALITY III.

20	2,134	67	2.4	14					
25	1,620	90	3.2	20					
30	1,304	109	3.9	25					
35	1,074	124	4.6	30					
40	924	136	5.2	34	6,200	2,330	15	.51	
45	827	145	5.7	37	8,600	3,000	22	.56	
50	755	153	6.1	40	10,900	3,500	28	.57	2
55	703	159	6.4	42	13,000	3,860	32	.57	
60	664	164	6.7	45	14,900	4,150	36	.57	4
65	634	168	7.0	47	16,500	4,390	39	.56	2
70	609	172	7.2	49	17,800	4,590	41	.55	5
75	588	176	7.4	50	18,900	4,760	43	.54	1
80	569	180	7.6	52	19,800	4,920	45	.53	
85	551	183	7.8	53	20,600	5,050	47	.52	
90	533	186	8.0	55	21,300	5,170	48	.51	
95	516	189	8.2	56	21,900	5,260	49	.50	1
100	499	192	8.4	57	22,500	5,340	50	.49	
									16

¹ Yield from suppressed and dead trees ignored. See Table 53 for actual figures on which this yield table is based.² Based on 59 plots, in even-aged old pasture stands; area 13.1 acres, taken in Oxford and Penobscot Counties, Me.; Coos, Grafton, and Sullivan Counties, N. H.; Caledonia and Windsor Counties, Vt.³ Trees 7 inches and over in diameter breast high; scaled by the New Hampshire Rule; top diameter inside bark, 6 inches, stump height, 1 foot.⁴ Trees 4 inches and over in diameter breast high; top diameter outside bark, 4 inches, stump height, 1 foot.⁵ Trees 6 inches and over in diameter breast high; top diameter outside bark, 5 inches, stump height, 1 foot.

TABLE 18.—Norway spruce ¹ (*Picea excelsa*). Normal yield table for northern and central Germany.

QUALITY I.

Age.	Number of trees per acre.	Basal area. ²	Average height.	Diameter of average tree. ³	Yield per acre. ³	Forest form factor.
<i>Years.</i>		<i>Sq. ft.</i>	<i>Feet.</i>	<i>Inches.</i>	<i>Cu. ft.</i>	
40	1,254	194.8	47.9	5.4	4,973	0.531
50	799	216.1	61.4	7.2	7,067	.533
60	557	231.5	72.4	8.9	8,798	.525
70	421	241.8	81.3	10.4	10,227	.520
80	340	250.7	88.6	11.8	11,425	.514
90	284	259.2	94.8	13.2	12,457	.507
100	247	266.7	100.0	14.4	13,367	.501

QUALITY II.

40	1,924	140.8	30.2	3.7	2,115	0.495
50	1,216	162.4	42.0	4.9	3,673	.534
60	840	178.9	52.2	6.2	5,059	.539
70	628	189.2	61.0	7.4	6,274	.539
80	500	200.0	67.9	8.5	7,317	.534
90	424	209.5	73.5	9.5	8,217	.528
100	380	217.7	78.4	10.2	8,960	.522

QUALITY III.

40	3,587	95.5	17.6	2.3	638	0.380
50	1,969	116.3	25.3	3.3	1,410	.479
60	1,270	131.3	33.3	4.5	2,403	.550
70	928	142.5	41.1	5.4	3,344	.571
80	750	152.2	47.2	6.2	4,161	.579
90	651	160.6	51.8	6.8	4,823	.580
100	597	167.3	55.4	7.3	5,352	.577

¹ From "Wachstum und Ertrag normaler Fichtenbestände," by Adam Schwappach, Berlin, 1890, as translated by H. S. Graves (pp. 417 and 418, Forest Mensuration, New York, 1906), revised on the basis of 3 instead of 5 quality classes.

² At 1.3 meters (4.27 feet) from the ground.

³ Derbholz (top diameter of 2.76 inches outside the bark).

A comparison ¹ of the values in Table 17 for red spruce with those of Table 18 for Norway spruce brings out the importance of good management in the development of stands. One of the first things to arrest the attention is the marked discrepancy between red spruce and Norway spruce in height and volume growth in Quality I. Even red spruce's advantage in having only its best growing trees included is insufficient to overbalance the deficiency in height. One's first impulse is to take this as confirming the widely accepted opinion that the growth qualities of red spruce are markedly inferior to those of Norway. Yet if that were so, the discrepancy would prevail throughout the three quality classes, which it does not do. It is considerably less marked in Quality II and disappears almost altogether in Quality III. To explain this difference, one must take into consideration the intensity of management of Norway spruce in the different quality classes. Thus, in Quality III, where Norway spruce was least intensively managed, thinnings began late, between

¹ In making the comparison it should be continually borne in mind (1) that the red spruce table is based on the measurement only of dominant and intermediate trees in 59 volunteer stands, whereas the other includes all green trees in 400 managed stands, four-fifths of which were artificially regenerated, and (2) that the utilization is not so close for red spruce as for Norway either in the top or at the stump.

the fortieth and forty-fifth year, and were light, about 2 trees in 7, or hardly more than the natural thinning which took place among the dominant and intermediate trees in the corresponding red spruce stands. The thinnings throughout, up to and including the one hundredth year, were in fact insufficient to make the number of trees the same in the Norway spruce stands as in the red spruce (dominant and intermediate trees) stands of corresponding age. Nevertheless, thinnings did accelerate the rate of growth somewhat, so that by the one hundredth year the whole Norway spruce stand, consisting of 98 more trees, very closely approximated the development attained by the red spruce dominant and intermediate trees. In the Quality II stands the effect of thinnings is more marked. Thinnings began in the thirty-fifth year, with an intensity of 3 trees in 7 removed (42 per cent); and continued comparatively heavy till the eightieth year, when they were 1 in 5 (20 per cent). The acceleration in this case is everywhere apparent. Shorter by 10 feet in the fortieth year, the whole Norway spruce stand had by the sixtieth year attained the same development as the dominant and intermediate red spruce stand of that age, and, while still lacking nearly 2 inches in average diameter, showed 9 cubic feet greater volume. By the eightieth year the total stems in the Norway spruce stand had been reduced to 3 less than the number of dominant and intermediate trees in the red spruce stand; had practically the same average diameter and 7 feet greater height; and being fuller boled, as indicated by the larger form factor, showed a very much accelerated volume growth. In Quality I, thinnings began in the twenty-fifth year on a scale slightly more than 3 in 7; and the entire stand with 586 more trees, had by the fortieth year surpassed in average height the average dominant and intermediate development of the red spruce stand of corresponding age and quality. This, with the fuller bole development, gave the Norway stand a considerable advantage in volume development, whether or not it accounts for all of the 1,313 cubic feet excess volume at that age. From that time on the red spruce stagnated and languished; but the Norway spruce, under the stimulus of frequent thinnings, increased steadily in every respect. The conclusion to be drawn from the comparison seems to be that lack of management rather than any inherent deficiency in growing qualities was the factor most largely responsible for the less favorable showing of red spruce.

METHODS OF CUTTING.

The methods of cutting to secure the natural regeneration of spruce depend in a large measure upon whether the stand to be perpetuated is of the selection, or many-aged form, as represented by the virgin and the cull forests, or of the even-aged form, such as those coming in after fire or windfall, or on abandoned pastures.

SELECTION CUTTINGS.

On account of the tolerance of spruce, it is well adapted to a selection system of management by which only the older trees of the main stand are removed and the necessary conditions thus established for the development of a new young growth. When this system is strictly carried out, the forest should be cut over annually, and only the very oldest and largest trees and those of least promising growth removed. In forests constituted as ours are at present, such a procedure would be impossible of accomplishment under any other than State ownership, which might put other considerations above revenue.

Cutting to a diameter limit, now quite generally practiced by lumbermen in the spruce regions, is a modification of the selection system by which a sufficient yield to make the individual cutting operations profitable is secured periodically. The amount cut each period and the interval between the successive cuttings vary, of course, with the diameter limit used.

In order to obtain satisfactory results under this system, a careful scrutiny is required of those trees immediately above and below the set diameter limit that their relations to others and to the best interests of the stand to be left may be ascertained. A fixed diameter limit is used in making computations to forecast the yield; but its application by "rule of thumb" in actual practice may defeat the purpose of the system. In the woods the diameter limit is best used simply as a guide. In general the largest trees should be cut, since their rate of growth is below that which would make their retention a profitable investment. They are likewise occupying space which would be more profitably used by younger and more rapidly growing trees. Approaching the diameter limit there are trees both above and below the established limit which should be cut because they have a poor crown, are stunted, or otherwise defective, so that their present worth would be lost if they were to be left until the next cutting. On the other hand, trees above the prescribed diameter limit which give every indication of being in thrifty growing condition should unquestionably be left, since their worth will be materially enhanced by allowing them to remain until the next cut is made. Trees of inferior species, as balsam and most of the hardwoods, which are interfering with the best development of the spruce, should be cut whenever possible.

Thus while the prescribed diameter limit may be 14 inches, the approximate minimum size to be taken may be 5 inches. Other things being equal, this minimum size will depend upon the market and the object of management. To insure a utilization of at least two-thirds of the stem height, no sound spruce tree should be cut for lumber smaller than 10 inches in diameter at breastheight and for pulp none smaller than 5 inches in diameter. These minima should

be raised to 11 inches and 6 inches, respectively, for stands averaging from 65 to 85 feet tall and to 12 inches and 6 inches for all stands over 85 feet tall.

It is not feasible to remove the defective trees which will not yield sufficient material to offset at least the cost of logging, except in localities where there is a high fire hazard or as a precaution against the spread of insects or fungous disease. In this case the logging operation may well be taken advantage of to improve fire protection or sanitary conditions by felling and swamping badly defective and dead trees and snags.

Care must be taken to provide suitable conditions for reproducing the stand. Where there is balsam in mixture with spruce, the competition of this species in the young growth should be reduced as far as possible by cutting the balsam in the main stand to as low a diameter limit as market conditions will warrant, thus reducing the number of balsam left for seed dispersal. Where the species in mixture are hardwoods, the same procedure will apply, although the elimination of the hardwoods need not be carried out so severely, for the reason that their effective range of seed dispersal is not so great as that of balsam. A more severe cutting of the hardwoods may be necessary, however, where there is much advanced young growth of spruce which requires to be released from shade to encourage its more rapid development.

Spruce should be favored in preference to balsam and most hardwoods for the reason that it is much less aggressive than the others and usually of the more value and desirability. Where conditions are favorable to the development of white pine and ash and possibly also basswood and red oak, they should be given the preference over spruce, since they are more valuable and less able to maintain themselves in competition with spruce, being less tolerant of shade.

It is impracticable to trust to the loggers to put the diameter limit into effect, and it is here that many spruce operators fail to secure the full benefit of the system's application. The trees to be cut should be marked beforehand by a man competent to judge the needs and requirements of the stand from the standpoint of both the forester and the operator. The fact that some companies which have tried marking claim that the results attained under the one method and the other do not materially differ does not prove the impracticability of the method, but reflects rather on the lack of trained judgment of the men whom they have employed to do the marking.

GROUPWISE CUTTINGS.

For general use the selection system in one of its forms is undoubtedly best suited to the management of spruce, particularly in lumber operations. Nevertheless it has its limitations. The degree of severity with which a stand must be cut to make the operation profitable

is important particularly in the swamp type and on the more exposed slope situations where there is great danger from windfall. In such situations the cuttings should be very light, so that the main crown cover will continue relatively undisturbed, or everything merchantable on a given area should be cut. This will virtually amount to clean cutting, for the nonmerchantable material left will almost inevitably be blown down.

If the individual cutting area is small, of only one or two acres in extent, and flanked by spruce growth either on its windward side or above it, reseedling from trees standing on the adjacent area will take place following clean cutting. Thus on a level, low-lying area groups or patches of timber may be selected for removal and the surrounding uncut areas depended upon to furnish the necessary seed for reproduction. In such a case subsequent cuttings would extend these areas gradually until the whole was cut over.

The exact shape and size of the area to be clean cut, as well as the selection of the initial points of attack in starting a groupwise cutting, depend on circumstances and the object it is desired to attain. Areas of advanced young growth may occur under the old woods, which it is desirable to free from shading and allow to develop; advantage may be taken of groups of overmature or insect-infested trees which are stagnating or declining in growth and value and which require cutting to prevent loss; or it might be desired to replace groups of mixed spruce and hardwoods by pure spruce, or to make an opening to encourage pine, ash, or other more valuable species.

The chief objection to this method in practice is that to insure effective reproduction the cleared areas should not exceed from 100 to 150 feet across. These should be separated by a sufficient amount of uncut timber to protect the cleared area from too severe exposure to sun and wind and insure the remaining stand against being blown down. For economical lumbering, however, a larger area would often be desirable.

CLEAN CUTTING IN STRIPS.

A better method for extensive cuttings in areas susceptible to windthrow is to distribute the clean cutting in strips in such a manner that the long way of the strip is at right angles, or nearly so, to the direction of the prevailing storm winds. Reproduction of the cleared areas would be secured by seeds disseminated from the trees in the intervening uncut timber belts which should be left intact at the time of the first cutting, or only very lightly thinned by removing small, or overtopped and dying trees without disturbing the main crown cover. Whether it is advisable to thin or not depends upon the degree of liability to windthrow, and upon the depth of the strips in the direction of the prevailing high winds. Instead of the sides of the strips in the cutting area being straight, they may be undu-

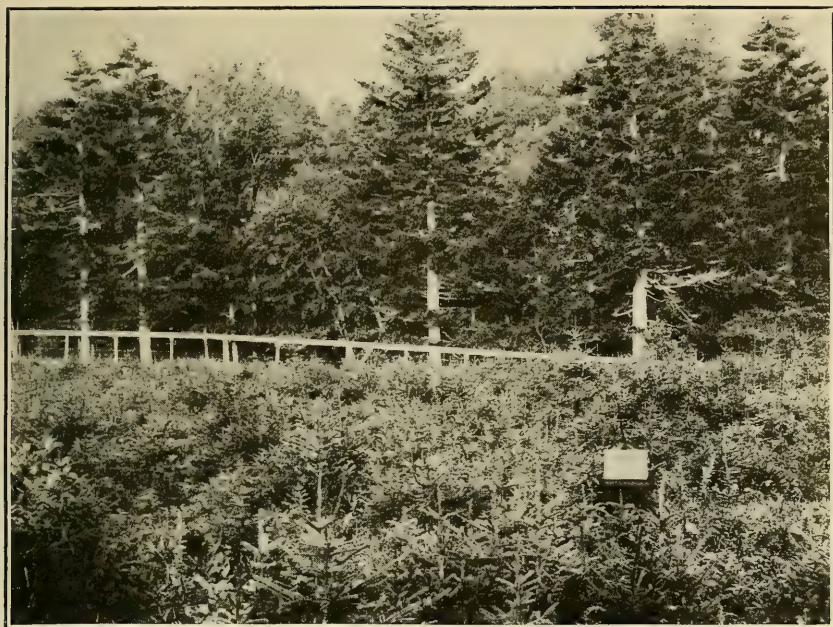


FIG. 1.—SEED TREES NEAR AT HAND. STOCKING DENSE IN CONSEQUENCE.



FIG. 2.—SEED TREES AT A DISTANCE. STOCKING IN GROUPS AND AS WIDELY SCATTERED INDIVIDUALS.

GENESIS OF OLD FIELD SPRUCE STANDS.

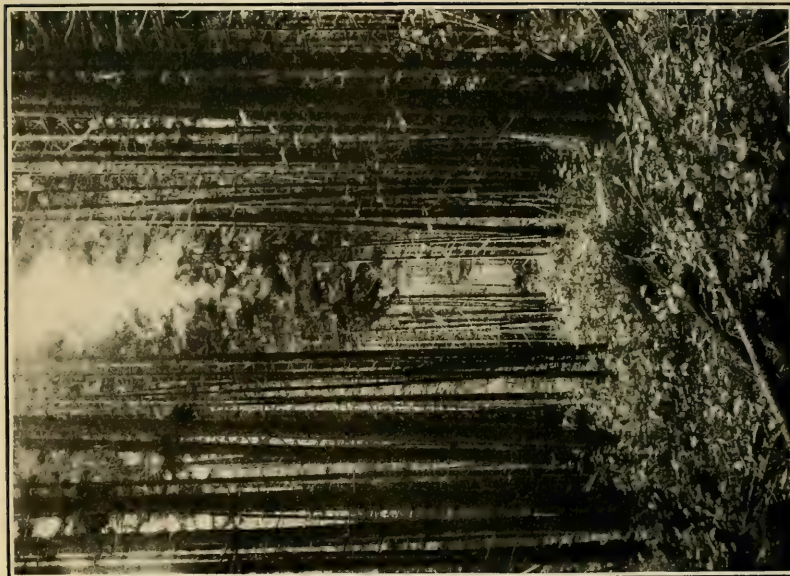


FIG. 2.—THE SAME CUTTING (NOT THE SAME ALLEY) AFTER 7 YEARS. GOOD SPRUCE AND BALSAM REPRODUCTION UNDER THE LIGHT COVER OF SEEDLING HARDWOODS.

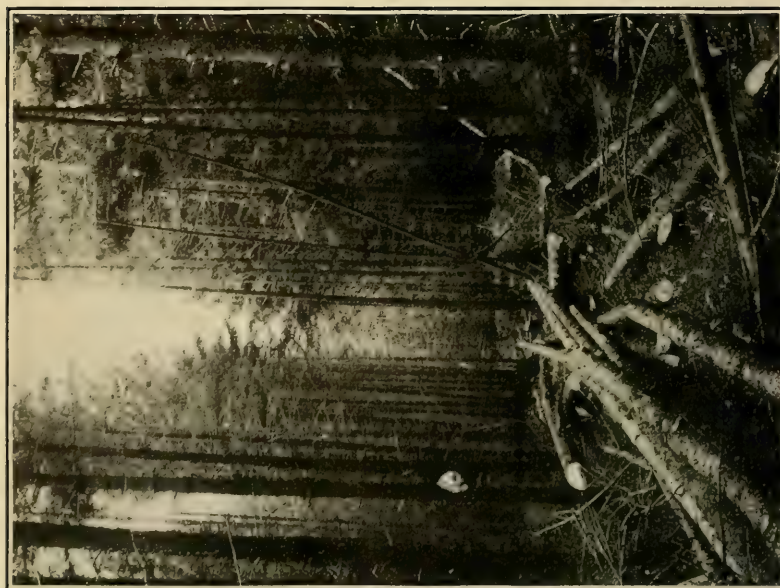


FIG. 1.—CLEAN CUT STRIPS 10 FEET WIDE AND RESERVE STRIPS 20 FEET WIDE (APPROXIMATELY); 38 PER CENT (13 CORDS) OF THE VOLUME REMOVED.

STRIP CUTTING IN OLD FIELD SPRUCE.

lating or saw-toothed, like a series of wedges or triangles with their bases on line. This modification is rather commonly used with spruce abroad.

Effectiveness in securing reproduction with the strip plan will depend upon the width of the strips employed. Satisfactory restocking of the cleared area can not be expected on a strip wider than twice the height of the trees in the adjacent stand; not because of inability to secure effective seed dispersal at even a great distance, but because of the effect upon seed germination and growth. Too extensive cutting will expose the soil to drying influences detrimental to spruce reproduction and at the same time create a condition favorable to the development of hardwoods, raspberry, and other perennials and weed growth in general.

Satisfactory reproduction in the reserve strips must be secured as advanced growth from seed trees standing on those strips, or the cutting of the reserve strips must be delayed until the trees on the strips first cleared are large enough to supply the necessary seed. A spruce stand in which windfirmness has been especially developed by periodic thinning from early youth may be reproduced by the shelter-wood compartment method. Such stands, however, can hardly be said to exist in this country at the present time. Thinnings of the severity of shelter-wood cuttings are largely out of the question in the previously unthinned stands of either virgin or old-field spruce which it is desirable to manage under a system of clean cutting in strips.

To insure an early second cut and prompt and effective regeneration, alternate cut and uncut strips not over 75 feet in width should be employed. By the adoption of strips of this width reproduction would not only be reasonably assured to the cleared strips but the side light and extra ventilation which would be let into the uncleared strips would be sufficient to create a condition favorable to satisfactory reproduction there also. For the dense, even-aged, old-field stands, strips as narrow as 10 feet with 20-foot reserve strips intervening have been recommended.¹ The final clearing of the area under such a system should be possible within 10 or 15 years after the first cut. This will enable the harvesting of a third or more of the crop at one cut. The cost will of course be somewhat more than if wider strips or clean cutting in a solid block were practiced. The yield and operating cost per unit of area should not, however, be materially different from that which would result from cutting to a diameter limit of 14 inches, except that slightly greater expense would attach to the handling and marketing of the smaller material which the clean cuttings would yield.

¹ "Forestry in New England," by R. C. Hawley and A. F. Hawes, p. 226.

The use of strips up to 300 feet wide or more will reduce the cost of logging but will delay the cutting of the second half of the area until the trees on the first half become large enough to furnish the necessary seed for reproducing it when cut over. This will delay the second cut to between the sixtieth and seventy-fifth year and require a rotation for each half of the stand of from 120 to 150 years. Complete stocking on the entire 300 feet of clearing could hardly be expected short of 3 and possibly 4 seed years; that is, from 15 to 18 years. Birch, aspen, beech, maple, and other hardwoods, and raspberries and other perennials will almost surely come in during the interval, whether the area is burned over or not. Spruce, however, will seed in beneath; and while that which comes in first where the cover crop is dense will be retarded, that which comes in later will find conditions favorable to its rapid development, so that when the overwood thins out, this understory of spruce will develop largely as an even-aged stand. (See Fig. 2a.)

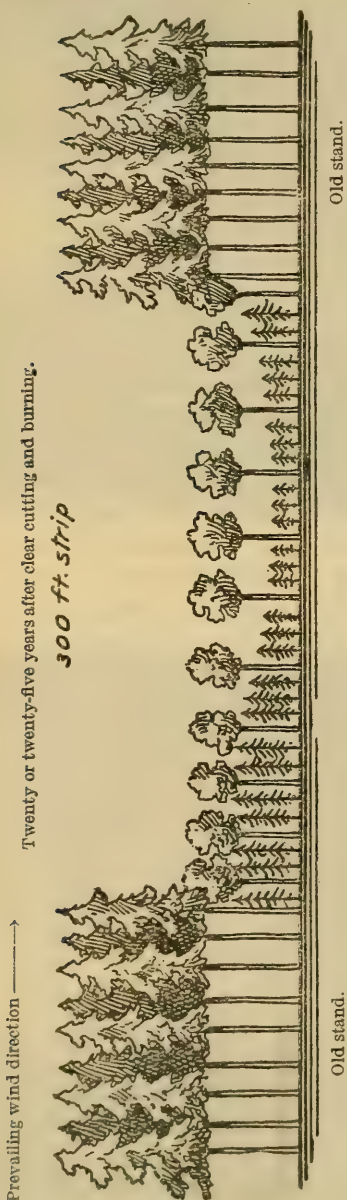


Fig. 2a.—Method of wide strip cuttings in spruce. Over wood of aspen, fire cherry, birch, and the like which came in following burning. Underwood of spruce. Spruce stocking complete in first and second seed years near the old stand. Third and fourth seed years required to establish satisfactory reproduction near the center of the strip.

dispersed in the early spring. Broadcast burning in the spring, therefore, as soon as the brush is dried out enough to burn readily, will destroy the duff and the seeds and spring germinates of the other

species and will expose mineral soil most opportunely for aspen seed to catch and take possession of the ground, followed by spruce in subsequent seed years.

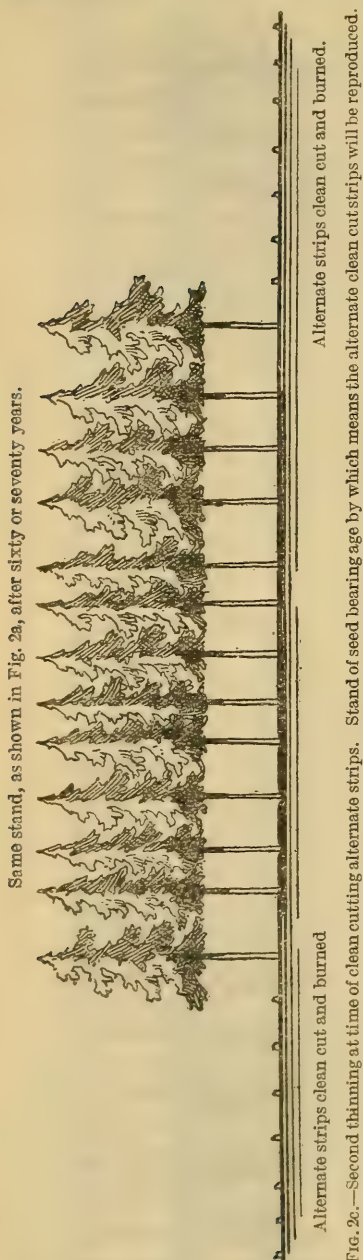
This method should prove satisfactory, particularly where spruce saw timber is desired. The early growth of the main stand under the cover crop would prevent the development of stout branches to such a height at least that one or more clear logs to each bole could be produced. The cover crop would reach merchantable size by about the fortieth or fiftieth year and could be harvested. (See Fig. 2b.) The main crop could be thinned at the same time to secure satisfactory distribution of the trees to be left. With the removal of the cover crop all spruce would be stimulated and rapid development follow. At the time of clean cutting the second area, in from the sixtieth to seventieth year, it would be profitable to thin the stand again on the first area. (Fig. 2c.) The final thinning of the first area would take place between the one hundredth and one hundred and twentieth year, when the removal of the cover crop and first thinning of the second area was made, thus at least three thinnings of the spruce would be possible with little or no additional expense. The cost of bringing the cut of spruce to maturity would be somewhat more under this lengthened rotation than under a shorter rotation, but this would be offset to a considerable extent by the intermediate revenues from the harvesting of the cover crop and the thinnings and by the better quality of timber yielded. The method could obviously only be employed

where there was an available market for the products yielded by the cover crop, namely, aspen pulp and excelsior stock, and maple



FIG. 2b.—Cover crop of aspen, fire cherry, etc., harvested, and spruce young growth thinned.

and birch firewood, spools, novelties, and the like. A permanent market for spruce of the quality produced would also be necessary.



IMPROVEMENT CUTTINGS.

With forests of the selection or many-aged form, thinnings, strictly speaking, merge to such an extent with the operations of harvesting the mature crops as to lose their identity. Thinnings and like operations, therefore, are applied to such forests only as are even-aged throughout or are made up of even-aged groups.

Improvement cuttings are divided successively into the following classes: cleanings, liberation cuttings, and thinnings. Pruning is also an improvement operation, but in this country, and particularly in the case of spruce, will be scantily employed. Pruning involves a direct investment of money from which only an indirect benefit is derived. With a short rotation, pruning makes possible the securing of a larger percentage of clear logs capable of yielding upper grades of lumber. Aside from so-called "fiddle butts" for piano board and violin stock and clear logs for siding material, the difference in price at the present time between the various grades of spruce will not justify an investment for pruning.

Cleanings.—Cleanings are particularly adapted to bring about favorable results in the mixed spruce and hardwood growths which come in after clean cutting and burning. Such worthless material as fire cherry and the slow-growing beech and sugar maple may be removed from young stands, and the birch and popple thinned. The most advantageous time is about the fifth year after the spruce has come in under the hardwood cover, since at that age

spruce has fully established its roots in the mineral soil and is ready to grow rapidly in height. Cleanings may also be resorted to in old-field

spruce stands to eliminate spruce or balsam advance growth and to reduce the percentage of balsam in the stand. Cuttings of this sort are indirectly remunerative, in the sense that they operate to shorten the rotation and thus bring the final yield nearer at hand; but care must be taken to remove only what is necessary to accomplish the purpose of the operation, otherwise the cost will be too great.

Liberation cuttings.—In the mixed selection stands, it often happens that a large spreading maple or other hardwood is retarding the development of a group of young spruce. The removal of such a tree for that reason would be a liberation cutting. It will generally happen, though, that immediate financial considerations as to whether or not the tree is worth cutting will govern, and that such a cutting will be made a part of the regular logging operation. Similarly the removal of this class of tree from second growth stands will form a part of the operation of thinning. Because such trees are larger than the others in the stand, their removal may constitute a determining factor in making a thinning profitable. A liberation cutting will not often be made alone, although in certain instances it will justify itself by making possible a large final yield.

Thinnings.—Thinnings are particularly desirable in the dense, even-aged stands resulting from natural seeding. Such stands not infrequently have upwards of 4,000 trees per acre, with an average growing space of about 10 square feet per tree at 30 years of age. As compared to this, a planted stand spaced 6 by 6 feet apart would have but 1,210 trees per acre, with a growing space per tree of 36 square feet. Even where the aggregate number of trees in the natural stand is less than that indicated, the tendency of spruce to germinate in clumps about the more favorable seed bed spots gives rise to a crowding which is every bit as undesirable as though the area were uniformly congested.

On account of the extreme tenacity with which spruce hangs on when once it has its roots established in the soil, it is not able to free itself in the struggle for supremacy with anything like the facility of the less tolerant species. As a result, a long period of stagnation, in which both the height and diameter growth suffer, follows the closing of the crown cover. These stands, if allowed to continue in their overcrowded condition until they are from 50 to 60 years of age, will often contain as many dominant and intermediate trees to the acre as the planted stand would have to start with, and will be composed of small-topped, spindling trees, averaging not more than 6 or 7 inches in diameter; and not more than one-half of the total volume will be merchantable. Under such conditions, also, the stand can not be thinned profitably. The cost of getting out the amount of product to be secured from a first thinning in such a stand

would be prohibitive. The remaining trees would be particularly liable to windthrow, and the thinning would produce doubtful results in securing an accelerated growth. With the attainment of their principal height growth, the trees composing a crowded stand have adjusted themselves through the abnormal reduction of their crown surface to the restricted growing space, and the possibilities of stimulating the growth in such a stand are not promising, unless the stand is to be left intact for upwards of 30 years afterward.

The principle to be followed in making thinnings depends upon the object of management and the age when thinnings can be begun. If it be desired to secure the maximum volume production, which culminates, according to Table 14, between the thirty-fifth and seventieth year, depending on the unit of volume and the site quality, thinnings should be undertaken by the twenty-fifth or thirtieth year on the best sites and be confined to the dominant and intermediate trees. If, however, quality production is the object desired, the first thinnings may be delayed until the thirty-fifth or fortieth year, being confined to the lower and intermediate crown classes until the sixtieth or seventieth year. This would especially encourage the development of form and quality. Thereafter the stand would be thinned more heavily. The last third of the rotation, or approximately after the eightieth or the one hundredth year, the cuttings would be in the form of accretion cuttings which would isolate a certain number of the best trees for the encouragement of a more rapid growth in volume.

The object of thinnings for volume production should be to free the tallest trees and gradually reduce their numbers without removing the weakest, except where they have a dry top, since they assist natural pruning, cover and protect the soil, and add to the strength of a close canopy. In the early period, when the trees are only to a limited extent merchantable, the fewest number of trees possible should be removed. The greatest advantage, accordingly, can be derived by cutting only those trees which occupy a position in the upper crown level, but which are interfering with the development of the stronger growing individuals. This will relieve the intense struggle taking place among those trees which are finally to form the mature stand and will allow them to develop with a minimum of hindrance from their neighbors. To be most effective, thinnings should be frequent and light in early life and heavier and less frequent in later years. Such early thinnings, however, involve a considerable expense, while the later ones may render the stand liable to windthrow, so that it will often be necessary to compromise.

In judging of the need for thinning, the relation of the crown length to the total height of those trees which are to form the final cut should

be noted. This would ordinarily vary between 25 and 40 per cent, depending on whether maximum solid volume or board-foot volume was the desired object. However, the response to thinnings made in spruce having an average crown length of less than 25 per cent of the height will be exceedingly slow and for that reason of doubtful financial value.

In Table 19 an attempt is made to predict the yield due to accelerated growth to be obtained by thinnings made at different ages and with varying degrees of severity.

TABLE 19.—Yield from stands of average quality thinned for maximum volume production of pulpwood (unpeeled cords) based on the cutting of dominant (including codominant) and intermediate trees only. Minimum merchantable size, 6 inches in diameter at breastheight and 5 inches in diameter outside bark in the top.

4 THINNINGS.

Age of stand.	Number of dominant and intermediate trees.			Proportion of trees removed.	Merchantable volume of trees removed.	Final yield.	Total yield.	Equivalent mean annual growth.
	In fully stocked unthinned stands.	To be left after thinning.	To be removed in thinning.					
1	2	3	4	5	6	7	8	9
<i>Years.</i>					<i>Cords.</i>	<i>Cords.</i>	<i>Cords.</i>	<i>Cords.</i>
25	1,316	1,097	220	$\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$ $\frac{1}{4}$	4.9	-----	-----	-----
30	1,062	762	183		5.6	-----	-----	-----
35	890	635	152		7.4	-----	-----	-----
40	774		127		17.9	-----	-----	-----
45	605	-----	682	-----	-----	44	61.9	1.37

3 THINNINGS.

25	1,316	1,054	263	$\frac{1}{3}$ $\frac{1}{3}$ $\frac{1}{3}$ $\frac{1}{3}$	-----	-----	-----	-----
35	890	791	263		7.1	-----	-----	-----
45	697	593	198		9.5	-----	-----	-----
50	605	-----	724		16.6	-----	-----	-----
				-----	-----	44	60.6	1.21

2 THINNINGS.

30	1,062	849	212	$\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$	-----	-----	-----	-----
40	774	637	212		10.2	-----	-----	-----
			424		10.2	-----	-----	-----
50	605	-----	-----		-----	44	54.2	1.10

The basic values are taken from Table 17, giving the yields for unthinned, fully stocked, old-field spruce stands of second quality. The volume production of these stands reaches a maximum in the fifty-fifth year and is 44 cords per acre. The assumption is made in Table 19 that 4 thinnings will reduce the natural rotation 10 years;

while for 3 and 2 thinnings 5 years will be saved in bringing the stand to maturity. The severity of each thinning is gauged so as to leave approximately the same number of trees as are shown by the yield table to be capable of growing under naturally competitive conditions at the end of the thinning period. Thus, in the case of the series of 4 thinnings, the first one in the twenty-fifth year reduces the number of trees from 1,316 to 1,097, which not quite approximates the condition which would be brought about by natural selection in the succeeding 5 years. The normal number of trees in unthinned stands (column 2) does not enter into the calculation but is included only for comparison to show how far each thinning will eliminate competition during the period.

All first thinnings, according to the table, show no remunerative yield. They are accordingly made light to reduce as far as possible the expense involved in making them. The maintaining of a reasonable density is also a consideration in making the thinning light, thus improving the form and quality of the final yield. With four thinnings the number of trees is not sufficiently reduced in any one thinning so that a normal density will not be restored within 5 years. With the 3 thinnings the number of trees is reduced in each case somewhat below the normal for a fully stocked stand of 5 years greater age. For example, the first thinning at 25 years reduces the number of trees to 1,054, while the normal density for 30-year stands is 1,062. With 2 thinnings the cut is heavier still. In each case, however, there is little doubt that the crown cover will be reestablished in 5 years.

In calculating the volume of each thinning the volume of the average tree in the yield table has been taken as a basis. The assumption introduces a plus error, since doubtless the average of the trees taken out will not in all cases be the same as the average of the stand. Yet any error which may arise from this cause will be more than offset by the fact that in addition to the indicated number of dominant and intermediate trees taken an unestimated amount will be yielded by suppressed and dead trees taken at the same time. The final yield also is based exclusively on that to be obtained from dominant and intermediate trees, while the suppressed and dead will doubtless yield several cords additional at the final cutting.

In the absence of graded mill tallies for second-growth spruce it is not possible to determine the rotation yielding the highest quality increment. Table 20, however, attempts to show the intermediate and final yield in board feet for spruce which has started under a light hardwood cover and been managed under the wide strip system outlined elsewhere.

TABLE 20.—*Yield from stands thinned for production of superior quality lumber, based on the cutting of dominant (including codominant) and intermediate trees only. Minimum merchantable size, 7 inches in diameter at breastheight and 6 inches in diameter outside bark in the top.*

Age of stand.	Number of dominant and intermediate trees only.			Proportion of trees removed.	Merchantable volume of trees removed.	Final yield.	Total yield.	Equivalent mean annual growth.
	In fully stocked unthinned stands.	To be left after thinning.	To be removed in thinning.					
1	2	3	4	5	6	7	8	9
<i>Years.</i>					<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>	<i>Bd. ft.</i>
45.....	1,316	1,053	263	$\frac{1}{2}$				
55.....	890							
55.....	697	514	129	$\frac{1}{2}$	3,870			
75.....	605							
85.....	551							
95.....	516							
105.....	492	347	116	$\frac{1}{4}$	7,775			
115.....	472							
					11,645			
120.....	463					25,630	37,275	310

It has been assumed in this case that at the time of removal of the hardwood cover, in the forty-fifth year, the understory of spruce would have a development parallel to that of a 25-year-old stand which had started in the open. Thus by adding 20 years to the different ages given in Table 17 the equivalent yields in unthinned stands up to 120 years are obtained.

The first thinning is indicated to be light and unremunerative, but there would doubtless be yielded at least a small amount of cordwood, which would be the class of material chiefly yielded by the cover crop of aspen, birch, and other hardwoods taken out at this cutting. The cut, as a whole, should therefore show a fair profit. This thinning would reduce the number of dominant and intermediate trees in the stand to a spacing of about 7 by 6 feet or that found in a normal unthinned stand seven years older, although the cover would doubtless entirely close in five years or less. The relief from competition should, however, occasion such an acceleration in growth for the 20-year period before the next thinning as to gain 5 years over the unthinned stand. Thus the stand at the next thinning, in the sixty-fifth year, would have the development shown for 70-year-old unthinned stands, or 643 dominant and intermediate trees to the acre.

From the sixty-fifth year on to the one hundred and fifth year, when the third thinning would take place, the reduction in numbers in natural unthinned stands is very gradual, 54 between the seventieth and seventy-fifth years, and but 11 between the one hundredth and one hundred and fifth years. The removal of one tree in five from the dominant and intermediate crown classes at the sixty-fifth year would consequently reduce the number of stems to that

found in a fully stocked unthinned stand of 95 years. The means this thinning would afford for the enlargement of the crowns of the remaining trees should make it possible to sustain such a rate of growth for the 40-year period as would bring the thinned stand at 105 years to a state of development equal to the unthinned 120-year-old stand. This would require a periodic mean annual growth of but 350 board feet, which should be easily possible, since in the unthinned stands it is 500 board feet per annum for the period from the seventieth to the seventy-fifth years and 360 board feet per annum from the eightieth to the eighty-fifth, with a mean for the 40-year period of 280 board feet per annum.

The final thinning in the one hundred and fifth year would be increased in severity so as to take out 1 tree in every 4 in the dominant and intermediate crown classes, thus reducing the number of trees remaining in these classes to 347 and the volume to 23,300 board feet in round numbers.

The calculation of the final yield is based on the assumption that the volume will increase at the same rate per cent in the final 15 years in the thinned stand as in the unthinned stand. This gives an average volume for the 347 trees of 74 board feet per tree, corresponding to a tree 9.5 inches in diameter at breast height and 65 feet tall, which is well within the limits of reason.

These calculations, like those on cord yields, leave out of consideration entirely all intermediate or final yields to be obtained in cutting suppressed and dead trees, which in the aggregate would be considerable, thus making the predictions amply conservative.

Doubtless on the rotations after the first one, except in exposed situations, the final removal of the crop might be begun in the ninety-fifth or one hundredth year under the shelter-wood compartment method. This would render the two cutting areas suggested in the original plan independent of one another, so far as seeding was concerned; would eliminate the intermediate hardwood crop, and would enable the rotation to be materially shortened. In such a case it might be well to introduce another thinning about the eighty-fifth year. A too-intensive system of management, however, for the production of first quality spruce sawlogs will not be justified. Competition with white pine similarly managed would make such an undertaking entirely unprofitable.

Figure 3, based on actual measurements in old-field spruce stands, shows graphically the influence the number of trees per acre has upon the development of the stand, particularly on average breast-high diameter and yield.

Overcrowding in plot 39 is particularly apparent from the underdevelopment of breast-high diameter and of board-foot contents. In contrast with this is the understocking in plot 17, which gave rise

to an abnormal diameter development as well as of board-foot contents and a less-than-normal cubic and cord volume. The full effect of understocking is obviously obscured by the better-than-average height development of plot 17, which amounts to more than 10 feet above the average and would occasion a 12 to 15 per cent increase in volume. The subnormal total basal area is the best index in this case. As is to be expected, the overstocked stand, plot 39, shows a maximum cubic and cord volume. Plot 46 illustrates very well the benefits to be derived from a slight understocking such as would be

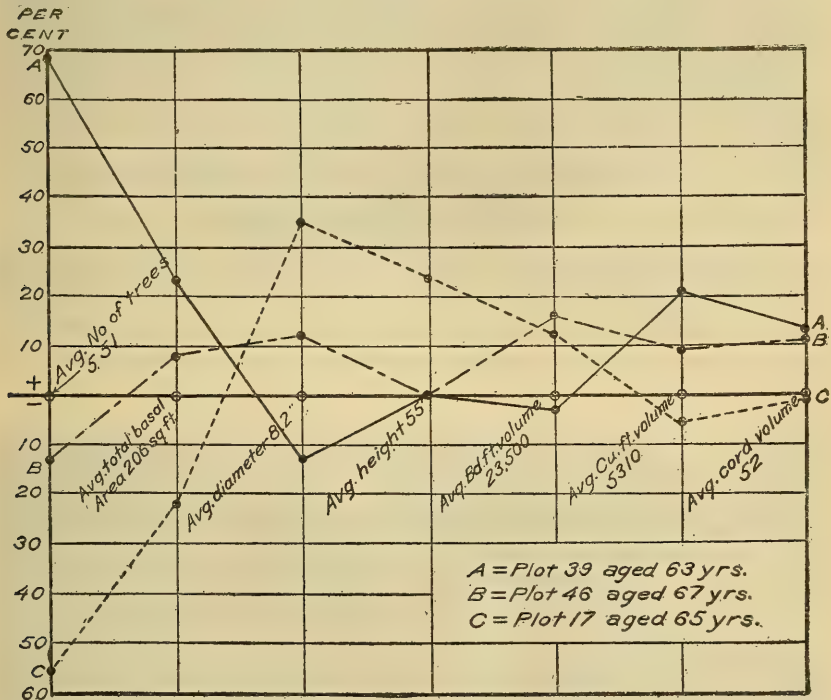


FIG. 3.—Effect of stocking on yield. Comparison of actual measurements of sample plots approximately 65 years old, with the average measurements for a 65-year-old stand in the second growth yield table. All stands Quality II and measurements are for dominant (including codominant) and intermediate trees only. Plottings are in percentages of the normal or average values of the different factors.

brought about by thinning. Thus, with a normal height growth a 13 per cent understocking was accompanied in this instance by increases of 8 per cent in basal area, 12 per cent in average diameter, 16 per cent in board-foot yield, 9 per cent in cubic-foot yield, an 11 per cent in cordwood yield.

BRUSH DISPOSAL.

One of the most potent sources of danger to spruce forests in general is the brush and, more particularly, the lops or branch wood which litter the ground after logging. The culled logs and tops from which the branches have been lopped do not of themselves constitute a

material source of danger, provided they are brought into contact with the soil and rapid decay thus induced. Spruce branch wood, however, on account of its resinous character, is particularly inflammable and resistant to decay, and constitutes a fire menace for several years when unlopped and from 7 to 10 years when lopped. In the forests where spruce is the predominating species, and particularly in the dense second-growth woods, an enormous quantity of such branch wood litters the cutting area. The ground is likewise covered with a dense mantle several inches in depth of dry needle litter, small twigs, and old cones. All this débris when exposed to the action of sun and wind with the cutting off of the forest cover, is quickly dried out and remains for several years an acute fire menace. The excessive branch-wood litter following lumbering and the deep humus cover also greatly hinder spruce reproduction on such areas and help the hardwoods and balsam to take possession through their superior ability to force their way to mineral soil.

When the selection system or other partial clearance cuttings are used or where the present age of spruce to be cut is not great, and where also a subsequent cut is dependent upon the maturing of seedlings or small trees which are on the ground at the time of the first cutting, the disposal of brush by burning is ordinarily not necessary unless the cut-over area is one on which there is special danger of fire getting a start.

BRANCH WOOD LOPPED AND SCATTERED OR PILED.

If only a little brush is produced and the fire danger is remote, the brush from the carefully lopped tops may be scattered about over the ground, thus hastening its decay. This method has given satisfaction where it has been tried in certain instances in the Adirondacks at a cost of from 15 to 25 cents per thousand board feet of lumber cut. Where more brush is produced than can safely be disposed of in this manner, the tops should be lopped and the branch wood piled. This will bring the larger material in contact with the soil, thus hastening decay. The segregation of the more inflammable material in compact bodies will reduce to a minimum the hindrance to reproduction and will effect a corresponding reduction in the danger from a rapid spread of fire should one start on the area.

BRUSH BURNED AS LOGGING PROCEEDS.

Excessive amounts of brush such as arise from the clean cutting of dense pure stands should be disposed of by burning. The most economical means of doing this is to burn the brush as the logging progresses. This is feasible when the ground is covered with snow or is damp so as to prevent the spread of fire. Small fires are started near each cutting crew and as the trees are felled the branches are lopped by the swampers and thrown into the fire. As the cutting

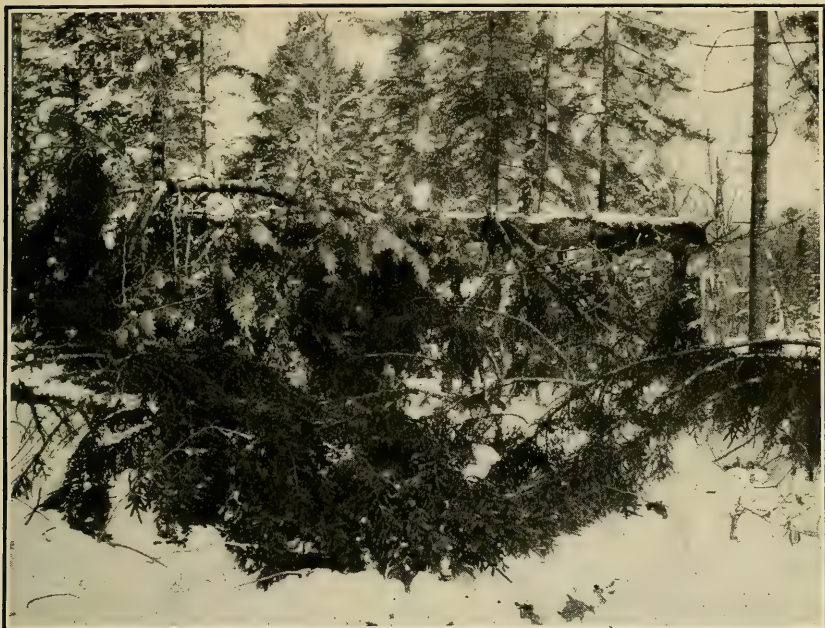


FIG. 1.—AN UNLOPPED TOP. A FIRE MENACE FOR FULLY 15 YEARS AFTER CUTTING.



FIG. 2.—A PROPERLY LOPPED TOP. ALL PARTS BROUGHT IN CONTACT WITH THE GROUND, PROMOTING DECAY AND THUS MATERIALLY REDUCING THE FIRE HAZARD AFTER FROM 5 TO 7 YEARS.

BRUSH DISPOSAL: TOP-LOPPING.



FIG. 1.—BRUSH PROPERLY PILED READY FOR BURNING.



FIG. 2.—BRUSH WHICH WAS CUT AND PILED IN SEPTEMBER BEING BURNED IN LATE DECEMBER (18 INCHES OF SNOW).

BRUSH DISPOSAL: PILED AND BURNING.

recedes from a fire and it is impracticable to build a new one, the whole top is hauled near the fire by the skidders before being trimmed.

The advantages of the method are several. The brush is disposed of as the logging proceeds, leaving the ground free for skidding. The cost of handling is kept to a minimum, since the branch wood is handled only once and does not require to be cut up small to insure being completely destroyed, since the tops burn readily, even on the snow or in stormy weather. The time of logging in these forests, particularly those in the Northeastern States and New York, is generally the late fall or early winter when the weather is damp or snowy and the danger of the fire spreading is almost negligible. By this method a minimum of area is burned over, which is of importance when there is young growth on the ground to be protected. A too dense young growth or deep snow at the time of logging makes the method impracticable, but for the stands here considered these hindrances will seldom be encountered.

BRUSH PILED FOR BURNING.

Where cutting is done in the spring for peeled pulp wood the weather conditions may not be favorable for the use of the method just described. In this case the brush would be piled when convenient and the burning deferred until subsequent damp weather or until after the first snow of the succeeding winter. Brush piling is best carried on in conjunction with the cutting and skidding operations. It is then only necessary to employ one extra man, who cuts up and piles the branches as they are lopped from the stem. The brush is thus immediately cleared away for the skidding of the logs and a second handling avoided, which means a considerable saving in expense. Then, too, more efficient work results when the men who trim the pile work together. Supervision is also less costly when the brush piling is made a part of the logging work than when it is a separate operation.

Brush piles should be small, not over 10 feet across and 6 feet high, with the branch wood closely and systematically piled, tops of the branches toward the center of the pile, the small branches in the bottom to facilitate the firing of the pile, and the piles well isolated from one another, from down logs, lopped tops, reproduction, and the trees to be left standing. Trimmed sticks leaned against the pile hold it in shape, keep it from being blown over, and render it more compact for burning. Compactness in piling is the key to efficient, clean burning. Loosely piled brush requires repiling or constant tending when burning to insure complete destruction, both of which operations are expensive. The cost of piling and burning varies with the condition of the stand between 10 and 50 cents per thousand board feet of timber cut.

BURNING THE PILED BRUSH.

Careful organization of the work should precede the burning of piled brush. A sufficient force of men equipped with fire-fighting implements should be on hand to prevent the fire from getting beyond control. Burning should not be attempted in windy or dry weather. The most opportune time is after the first snow of winter. The piles are then dry enough to burn well, except for the outer snow-covered layer. There is little or no danger of the fire running along the ground, and the snow cover on the branches of the standing trees affords the necessary protection against their injury by the rising flames. In the absence of snow, damp weather is essential to insure the ground being wet enough to prevent the spread of the fire. With a slight wind, other things being favorable, burning may take place, provided the fires are started on the leeward side of the area and progress against the wind. Likewise when brush is being burned on a slope the uppermost piles should be started first, the progress being from the upper to the lower level of the slopes. A further precaution is necessary where the piles are close, namely, that only every other or every third pile be fired at first and these allowed to burn down before the remaining ones are started. If all the piles are fired together, a strong uninterrupted upward current of heated air will inevitably cause injury to the remaining standing trees even if they have short crowns, well up from the ground. The alternate unburned piles act as a check by interposing cool air spaces, thus isolating separate fires.

BROADCAST BURNING.

Broadcast burning has been previously mentioned in connection with the clean cutting in strips of even-aged spruce stands. Here the object is not only to get rid of the large amount of brush which cuttings of this sort yield, but to eliminate as well the deep accumulation of undecomposed litter which greatly hinders the coming in of spruce seedlings and also constitutes a menace to what seedlings do succeed in getting established by endangering their future destruction by fire. It is also cheaper than piling and burning. In using this method the logging is conducted in the ordinary way, except that the tops are lopped to allow the mass a better opportunity to settle and thus facilitate clean burning.

The same or greater care must be exercised in using this method to insure its complete control. Favorable climatic conditions must be chosen and a well-equipped force of men provided. The slash should be fired at a time when it is dry enough to burn well, but not so dry as to endanger the adjoining timber and allow the fire to get beyond control. The brush in the open area will dry out more rapidly after a drenching rain or moderate fall of snow than will the timbered

area, so that if the fire is properly timed the brush can be burned while the timbered area is still too damp to burn freely.

Isolating and subdividing burning area.—The area to be burned over must first be isolated from the contiguous uncut areas by the clearing of all inflammable matter from wide strips on all sides. This may be accomplished by throwing all tops and lops for a distance of from 20 to 40 feet from the edge in toward the center of the cleared area. It would be preferable, though, to clear away, pile, and burn all brush on such strips in the manner previously described before attempting to burn the remainder. If the cleaned area is of considerable extent, a wise precaution would be to pile and burn similar fire lines through the middle, thus dividing the area into halves or quarters. If the area is small, the logging roads will serve as intermediate fire lines.

With the necessary control lines cleared and burned, the general burning would begin at the leeward side or along the upper end if the cleared strip is on a hillside. The plots between logging roads would serve as units for burning. Only alternate plots along the leeward or uphill front should be kindled, and these should be allowed to burn down before another set is fired.

The method is unquestionably more dangerous than burning in piles, demanding a larger force to handle it. Careful judgment in the choice of time for burning is essential. The method should never be employed where the mineral soil is thin or nearly lacking as is the case on many of the steep, boulder-strewn upper slopes in both New Hampshire and the Adirondacks. Under such circumstances the main purpose would be defeated and the slopes rendered barren and unproductive.

LIGHT BURNING.

Under certain conditions the annual or periodic burning of the litter under growing stands might be advisable. Where there are dense, even-aged, planted, or natural stands in which thinnings are not to be made and therefore humus disintegrations can not be controlled, an occasional light burning would afford protection from damage by an uncontrolled ground fire during a drought. The soil would also be put in a more receptive condition for reproduction when the final cutting was made. The operation requires extreme care, otherwise its purpose will be defeated.

The recommendation for the use of this means of fire protection and soil improvement is qualified and made contingent upon the adoption of the following precautions:

The stand to be thus treated must be established on moderately deep mineral soil.

Except where the slope is very gentle, any accumulation of litter should be removed from the upslope side of the trees before burning.

The burning should not be undertaken until the trees are sufficiently large to have developed a suitable thickness of corky bark to afford the necessary protection from injury, and are sufficiently cleared of their lower branches to afford opportunity for the fire tenders to get about easily and to control the fire.

In the absence of roads or other cleared areas which might be used for fire control, ground-cleared fire lines should be provided around the border and possibly at intervals within the stand, particularly if a hillside is to be burned.

Burning should be restricted to a time, preferably early spring, when the loose top litter is dry but the under layers and soil are damp. The burning must not be allowed to reach to mineral soil.

A sufficient force of men properly equipped for fire fighting should be in attendance to check a too deep burning and prevent the fire getting beyond control.

The plan of burning in strips along a well-defined and protected front with gradual progress away from it should be followed. All other precautions mentioned elsewhere should be carefully observed.

Light burning is not advisable in selection stands where the reproduction and young growth form a distinct asset, since they would inevitably be injured or destroyed. It has a place where dense, even-aged stands are to be cut clean and reproduced by natural regeneration methods, although too much emphasis can not be laid on the danger of fire escaping and the taking of every precaution necessary to prevent it.

SOWING AND PLANTING.

It is highly probable that it will eventually be found profitable to plant many of the spruce areas when they are cut over, rather than to wait for the slower and less certain restocking by natural means. This will come first on those areas at present covered with even-aged stands and such of the selection stands as are understocked with young growth or chiefly cut for pulp wood.

A comparison of yields will suffice to show the advantages to be attained by planting over cutting under the selection system. Thus the average yield per acre of spruce in Maine at the present time, cutting to a 12-inch diameter limit, is placed by lumbermen at about 2,000 board feet. With a diameter limit of 12 inches, a period of 49 years must elapse before a similar amount can again be harvested. It is obvious that a cut to 8 inches would still yield material of a size suitable for pulp wood and would increase the present cut per acre to about 3,000 feet board measure¹ (5 cords) and reduce proportionately the cost of logging. But with an 8-inch diameter limit it is

¹ The approximate correctness of this figure is borne out by a yield table prepared for the "Lower spruce and hardwood lands" in Maine, by Hosmer, appearing in the report of the forest commissioner, Maine, 1902.

quite probable that a second cut could not again be secured short of 100 years, and it would also be increasingly difficult, if not impossible, to secure satisfactory natural restocking.

By comparison the same land managed under a system of clean cutting and planting could reasonably be expected in 60 years to yield at least 50 cords from trees 8 inches and over in diameter at breast height and an additional 10 cords from trees between 6 and 8 inches, or a total of 60 cords. A further advantage, though of minor importance, is that with the planted stand the material produced would be uniformly of a size to be easily handled by hand in the bolt. If handled in the log, the cost of logging would be somewhat more than the cost of handling larger timber.

DIRECT SEEDING.

Under certain circumstances it may be found advantageous to sow the seed broadcast in the places where the future forest is to be, simulating methods of nature. This will give satisfactory results where an abundance of seed can be secured cheaply and where an extensive area too stony or otherwise encumbered to admit of planting economically is to be reforested, but only as the result is viewed from the standpoint of the whole. Acre for acre the result will be less satisfactory than planting, particularly in commercial reforestation, for there will be many bare places, which will increase the cost in proportion to the amount of land that lies unproductive throughout the life of the resulting crop. If the bare spots are planted later, that will increase the cost. Other methods of a more or less extensive character are: Broadcasting the seed on previously plowed strips; planting with a corn planter; or hand planting in prepared seed spots. These methods are not ordinarily well adapted to red spruce; for as the intensiveness of the method increases, the cost very nearly approaches that of planting seedlings, which would be much more likely to succeed.

PLANTING.

On account of the tenderness of spruce, its exacting demands on the quality of the seedbed, and its slow growth in early youth, much more satisfactory results will be obtained in reforestation by planting than by sowing. The choice of stock is of great importance. If the ground cover is dense, the soil wet or dry or subject to freezing, or if direct insolation is strong, especially thrifty plants must be used, such as three or four year old nursery transplants. For planting on an area from which the surface cover has been recently removed and the mineral soil exposed two-year-old nursery seedlings will suffice, provided the situation is sheltered and the too prolific development of brush and weeds can be prevented. A slight nurse cover for

spruce is of advantage during the period when it is becoming established. Where each tree represents an investment, however, the nurse cover must not be allowed to interfere with the seedling's normal development.

Costs.—The following cost data for red spruce are based on the experience of the State of New York in its reforestation operations:

Average market price of spruce seed (ranging in price from \$3 to \$7). per pound . .	\$4. 50
Cost of collecting seed	\$0. 90- 1. 50
Cost per thousand to raise 2-year-old seedlings (based on 500,000 seedlings annually)	1. 33
Three-year-old transplants	3. 23
Four-year-old transplants	3. 73

The cost per acre of making plantations, using various aged stock and different spacings was as follows: Using 2-year-old seedlings spaced 4 by 4 feet apart (2,722 trees per acre), \$11.79; spaced 5 by 5 feet (1,742 trees per acre), \$7.54; spaced 6 by 6 feet (1,210 trees per acre), \$5.24; using 3-year-old transplants spaced 4 by 4 feet, \$19.41; spaced 5 by 5 feet, \$12.42; spaced 6 by 6 feet, \$8.63; using 4-year-old transplants spaced 4 by 4 feet, \$22.67; spaced 5 by 5 feet, \$14.51; spaced 6 by 6 feet, \$10.08. No allowance is made in the above figures on planting for the cost of transporting the seedlings from the nursery to the planting site, since it is too variable.

SOURCES OF PLANTING STOCK.

Because of the slow growth in early life of red spruce planting stock, it is difficult to handle both in nursery transplanting and in the field where 2-year seedlings are used. This unquestionably will be a strong factor in limiting the planting of this species, since both white and Norway spruce (*Picea canadensis* and *P. excelsa*) are much more satisfactory in this respect. For small operations, the purchase of planting stock will usually be cheaper than the raising of home-grown stock. Where extensive planting is to be undertaken, however, the field planting and nursery work can be coordinated to advantage and placed under the direction of an experienced manager, in which event a local nursery is desirable.¹

The use of wild seedlings of this species, if collected as they occur in the woods without selection and transplanted directly to the permanent site, would yield very irregular and unsatisfactory results. Such stock would be of all sizes and of various ages from 1 to 10 or 15 years, with poorly developed, widely ramifying root systems and spindly tops. More uniform results would be obtained if the seedlings were set in nursery lines for a year, and a careful selection and grading made possible. The wild transplants would still be

¹ A detailed description of the subject of raising and planting coniferous seedlings will be found in Bulletin 76, Forest Service, U. S. Department of Agriculture, "How to Grow and Plant Conifers in the Northeastern States."

inferior to straight nursery-grown stock; and the expense of transplanting, tending in the nursery lines, and grading would bring their cost up to that of the more satisfactory nursery-grown seedlings.

SPACING IN PLANTING.

For general commercial planting a spacing of 5 by 6 feet or 6 by 6 feet apart is recommended. Moderately close planting is necessary with spruce to stimulate its growth in height and to provide for the closing of the crown cover and suppression of its lower branches. Such a stand properly thinned should show a final yield in 45 years of from 32 to 55 cords per acre in addition to the intermediate yields from thinnings. Wider planting, as, for instance, 8 by 8 feet or 8 by 10 feet, is advocated in some quarters to obviate the necessity of thinning under a short rotation for the production of pulpwood. The timber produced by such a method would be short, big-butted, with a quick taper, and clothed with green, or at best poorly suppressed, dead branches well down to the ground. Such a stand might be expected to yield between three-fourths and 1 cord per acre per annum with a 30 to 35 year rotation.

ROTATION.

Some consideration has already been given to the rotation in connection with the discussion of methods of cutting and of thinnings. As indicated in Table 17, a rotation of from 55 to 60 years under average, natural, even-aged conditions will yield a maximum of pulpwood volume. Judicious thinnings should reduce this rotation from 5 to 10 years, increasing the gross volume, including the volume of yield from thinnings, at the same time. For saw timber and dimension stuff a rotation of from 100 to 120 years should yield a satisfactory return under management for selection as well as even-aged forest conditions, as shown by Tables 15 and 16. In the case of selection forests, of course, the quantitative yield would be small as compared to even-aged stands, but this disadvantage should be offset to an appreciable extent by the better than average quality yield.

APPENDIX.

VOLUME TABLES.

The volume tables for spruce which follow are divided between the various units of measure and comprise 12 board-foot tables, 4 cubic-foot tables, and 3 cord tables.

Board-foot tables.—The board-foot tables are all for old-growth spruce, except one of the New Hampshire tables, which is for old-field spruce. Since a different log rule is in use in each of the four principal spruce States, the data in each State has been worked up by the Scribner Decimal C rule for purposes of comparison.

Of the four Maine tables two are based on the total height of the tree and two on the number of 16-foot logs, each according to the Scribner Decimal C and Maine log rules.

The New Hampshire tables are five, one of which, Table 29, is for second-growth spruce. The old-growth volumes are given in terms both of the New Hampshire and Scribner Decimal C rules on the basis of total height and number of 16-foot logs.

Both New York tables are according to the Scribner Decimal C rule, one of which is based on the total height of the tree and the other on the number of 16-foot logs. Although the Standard is not a board-foot measure at all, tables of volume in terms of Standards (Dimmick rule) on the basis of total height and of 16-foot logs are here included for purposes of comparison.

The West Virginia tables are divided between the Scribner Decimal C and Doyle rules, each on the basis of the total height of the tree and on the number of 16-foot logs.

Cubic-foot tables.—The cubic-foot tables (Nos. 38 to 41, inclusive) are all for old-growth spruce except No. 39 for New Hampshire, which is a combination of old-growth and "old-field" spruce. These tables being all for approximately the same utilization at stump and top, afford a good opportunity for comparison of development in the different localities. According to the tables given, the diameters and heights run about the same for Maine and New Hampshire, but the Maine trees are generally fuller bodied, as indicated by a larger cubic content for the same diameter and height. Had the New Hampshire data been from the northern instead of the southern part of the State, it would doubtless have exceeded that in Maine in height and diameter and in volume as well. This is because spruce

is generally believed to reach its New England optimum in northern New Hampshire. For equal heights and diameters Maine shows fuller-bodied boles than West Virginia, yet in general development West Virginia greatly excels.

Cordwood tables.—Old-field spruce is most commonly sold by the cord for pulp, sometimes rough and at other times peeled. Hence Tables 42, 43, and 44 were prepared for New Hampshire conditions, where old-field growth is most prevalent. Table 43, based on 5-inch utilization in the tops, was derived from Table 44 by interpolation. Table 43 was used for scaling the sample plots for Table 17.

TABLE 21.—Board-foot volume of red spruce in Maine, according to the Scribner Decimal C rule and total height of tree.

[CURVED.]

Diameter breast high.	Total height of tree—feet.						Basis.
	40	50	60	70	80	90	
	Volume—board feet.						
<i>Inches.</i>							<i>Trees.</i>
7.....	5	10	15	.....	.....	.....	8
8.....	15	20	25	.....	.....	.....	11
9.....	25	30	40	.....	.....	.....	18
10.....	35	45	55	60	.....	.....	29
11.....	50	60	70	80	.....	.....	21
12.....	60	80	90	110	.....	.....	27
13.....	80	100	120	130	.....	.....	20
14.....	90	120	140	160	170	.....	22
15.....	.....	140	170	190	200	.....	13
16.....	.....	160	200	220	240	260	11
17.....	.....	.....	230	250	280	310	14
18.....	.....	.....	260	290	330	360	19
19.....	.....	.....	.....	330	380	420	6
20.....	.....	.....	.....	380	430	480	6
21.....	.....	.....	.....	430	490	540	6
22.....	.....	.....	.....	480	550	610	4
23.....	.....	.....	.....	530	610	680	4
24.....	.....	.....	.....	.....	670	750	.....
25.....	.....	.....	.....	.....	730	830	2
							241

Based on taper curves, scaled as 8 and 16 foot logs. Stump height, 1 foot; diameter inside bark of top, 6 to 9 inches.

Data collected by R. S. Hosmer in Piscataquis County in 1902.

TABLE 22.—Board-foot volume of red spruce in Maine according to the Scribner Decimal C rule and number of 16-foot logs.

[CURVED.]

Diameter breast high.	Number of 16-foot logs.									Basis:
	1	1½	2	2½	3	3½	4	4½	5	
	Volume—board feet.									
<i>Inches.</i>										<i>Trees.</i>
7.....	10	20								8
8.....	15	25								11
9.....	20	30	35							13
10.....	25	40	50	60						29
11.....	35	50	70	80						21
12.....	40	60	80	100	110					27
13.....		70	100	120	130					20
14.....		90	120	140	160	170				22
15.....			140	170	190	200				13
16.....			160	190	220	240	270			11
17.....				220	250	280	310			14
18.....				250	280	320	360	400		19
19.....					330	370	410	450		6
20.....					370	410	450	500	550	6
21.....					410	450	500	560	620	6
22.....						490	560	620	690	4
23.....						540	610	690	770	4
24.....							670	760	850	
25.....							730	830	930	2
										241

Based on taper curves, scaled as 8 and 16 foot logs. Stump height, 1 foot; diameter inside bark of top, 6 to 9 inches.

Data collected by R. S. Hosmer in Piscataquis County in 1902.

TABLE 23.—Board-foot volume of red spruce in Maine according to the Maine rule and total height of tree.

[CURVED.]

Diameter breast high.	Total height of tree—feet.						Basis.
	40	50	60	70	80	90	
	Volume—board feet.						
<i>Inches.</i>							<i>Trees.</i>
7.....	15	20	25				8
8.....	25	35	40				11
9.....	40	50	60				18
10.....	50	70	80	90			29
11.....	60	80	100	110			21
12.....	80	100	120	130			27
13.....	90	120	140	160			20
14.....	110	140	170	190	210		22
15.....		170	190	220	250		13
16.....		190	220	250	280	310	11
17.....			250	290	320	360	14
18.....			270	320	370	410	19
19.....				360	410	460	6
20.....				400	450	520	6
21.....				440	500	580	6
22.....				480	550	630	4
23.....				520	600	690	4
24.....					650	750	
25.....					700	810	2
							241

Based on taper curves. Logs scaled in lengths of from 8 to 16 feet. Stump height, 1 foot; diameter inside bark of top, 6 inches.

Data collected by R. S. Hosmer in Piscataquis County in 1902.

TABLE 24.—Board-foot volume of red spruce in Maine according to the Maine rule and number of 16-foot logs.

[CURVED.]

Diameter breast high.	Number of 16-foot logs.								Basis.	
	1	1½	2	2½	3	3½	4	4½		
	Volume—board feet.									
<i>Inches.</i>									<i>Trees.</i>	
7.....	20	25	.....	.....	.....	.....	.....	.....	8	
8.....	30	35	40	.....	.....	.....	.....	.....	11	
9.....	35	45	50	.....	.....	.....	.....	.....	18	
10.....	45	50	70	80	.....	.....	.....	.....	29	
11.....	50	70	80	100	.....	.....	.....	.....	21	
12.....	60	80	100	110	140	.....	.....	.....	27	
13.....	.....	90	110	130	160	.....	.....	.....	20	
14.....	.....	.....	130	150	180	220	.....	.....	22	
15.....	.....	.....	150	170	210	240	.....	.....	13	
16.....	.....	.....	170	200	230	270	310	.....	11	
17.....	.....	.....	.....	220	260	300	350	.....	14	
18.....	.....	.....	.....	250	290	340	390	440	19	
19.....	.....	.....	.....	.....	330	370	420	480	6	
20.....	.....	.....	.....	.....	360	410	460	520	6	
21.....	.....	.....	.....	.....	390	450	510	570	6	
22.....	.....	.....	.....	.....	.....	500	560	620	4	
23.....	.....	.....	.....	.....	.....	550	610	680	4	
24.....	.....	.....	.....	.....	.....	.....	670	740	.....	
25.....	.....	.....	.....	.....	.....	.....	740	820	2	
										241

Based on taper curves. Logs scaled in lengths of from 8 to 16 feet. Stump height, 1 foot; diameter inside bark of top, 6 inches.

Data collected by R. S. Hosmer in Piscataquis County in 1902.

TABLE 25.—Board foot volume of red spruce in New Hampshire according to the Scribner Decimal C rule and total height of tree.

[CURVED.]

Diameter breast high.	Total height of tree—feet.						Basis.
	30	40	50	60	70	80	
	Volume—board feet.						
<i>Inches.</i>							<i>Trees.</i>
8.....	20	24	31	40	55	-----	76
9.....	26	32	40	52	67	-----	75
10.....	32	40	49	63	80	98	87
11.....	36	49	59	76	95	120	76
12.....	40	58	72	90	110	140	87
13.....	-----	68	85	100	130	160	54
14.....	-----	78	99	120	150	180	68
15.....	-----	90	110	140	170	210	33
16.....	-----	100	130	160	200	240	36
17.....	-----	120	150	180	230	270	24
18.....	-----	130	170	210	260	310	21
19.....	-----	-----	190	240	290	350	13
20.....	-----	-----	210	270	320	390	9
21.....	-----	-----	240	300	360	430	3
22.....	-----	-----	270	330	400	470	3
23.....	-----	-----	-----	370	440	520	-----
24.....	-----	-----	-----	410	480	570	-----
25.....	-----	-----	-----	450	530	620	-----
26.....	-----	-----	-----	490	580	670	3
-----							668

Based on taper curves; scaled mostly as 16.3-foot logs, with a few shorter logs where necessary. Stump height, 1 foot; diameter inside bark of top, 6 inches.

Data collected by T. S. Woolsey, jr., in Grafton County in 1903.

TABLE 26.—Board-foot volume of red spruce in New Hampshire according to the Scribner Decimal C rule and number of 16-foot logs.

[CURVED.]

Diameter breast high.	Number of 16-foot logs.							Basis.
	1	1½	2	2½	3	3½	4	
	Volume—board feet.							
<i>Inches.</i>								<i>Trees.</i>
8	20	30	43	59	-----	-----	-----	76
9	21	33	46	63	-----	-----	-----	75
10	22	37	50	69	89	-----	-----	87
11	23	42	56	76	98	-----	-----	76
12	24	48	63	85	110	140	-----	87
13	-----	56	72	95	120	150	-----	54
14	-----	65	81	110	130	170	210	68
15	-----	75	92	120	150	190	230	33
16	-----	-----	100	130	170	210	260	36
17	-----	-----	120	150	190	240	290	24
18	-----	-----	130	170	210	270	320	21
19	-----	-----	-----	190	240	300	350	13
20	-----	-----	-----	210	270	330	380	9
21	-----	-----	-----	240	300	360	420	3
22	-----	-----	-----	270	330	400	460	3
23	-----	-----	-----	-----	360	440	500	-----
24	-----	-----	-----	-----	400	480	550	-----
25	-----	-----	-----	-----	440	520	600	-----
26	-----	-----	-----	-----	480	560	650	3
								668

Based on taper curves; scaled mostly as 16.3-foot logs, with a few shorter logs where necessary.

Stump height, 1 foot; diameter inside bark of top, 6 inches.

Data collected by T. S. Woolsey, jr., in Grafton County in 1903.

TABLE 27.—Board-foot volume of red spruce in New Hampshire according to the New Hampshire rule and total height of tree.

[CURVED.]

Diameter breast high.	Total height of tree—feet.						Basis.
	30	40	50	60	70	80	
	Volume—board feet.						
<i>Inches.</i>							<i>Trees.</i>
8	26	30	36	44	51	-----	76
9	35	43	50	60	71	-----	75
10	45	56	66	78	91	100	87
11	58	70	83	97	110	120	76
12	72	85	100	120	130	150	87
13	-----	100	120	140	150	180	54
14	-----	120	140	160	180	210	68
15	-----	140	160	180	210	240	33
16	-----	160	180	210	240	270	36
17	-----	180	200	240	270	310	24
18	-----	200	230	270	300	350	21
19	-----	-----	260	300	340	390	13
20	-----	-----	290	330	380	430	9
21	-----	-----	320	360	420	470	3
22	-----	-----	350	400	460	510	3
23	-----	-----	-----	440	500	560	-----
24	-----	-----	-----	470	540	610	-----
25	-----	-----	-----	510	580	660	-----
26	-----	-----	-----	540	620	710	3
							668

Based on taper curves; scaled mostly as 16.3-foot logs, with a few shorter logs where necessary.

Stump height, 1 foot; diameter inside bark of top, 6 inches.

Data collected by T. S. Woolsey, jr., in Grafton County in 1903.

TABLE 28.—Board-foot volume of red spruce in New Hampshire according to the New Hampshire rule and number of 16-foot logs.

[CURVED.]

Diameter breast high.	Number of 16-foot logs.							Basis.
	1	1½	2	2½	3	3½	4	
	Volume—board feet.							
<i>Inches.</i>								<i>Trees.</i>
8	26	34	49	65				76
9	35	43	57	75				75
10	44	53	67	86	110			87
11	55	64	78	98	120			76
12	66	76	92	110	130	160		87
13		88	110	120	150	180		54
14		100	120	140	170	200	240	68
15		120	140	160	190	220	270	33
16			160	180	210	250	300	36
17			180	200	240	280	330	24
18			200	220	270	310	360	21
19				250	300	340	390	13
20				280	330	370	430	9
21				310	360	410	470	3
22				340	390	450	510	3
23					420	490	550	
24					460	530	590	
25					500	570	630	
26					540	610	670	3
								668

Based on taper curves; scaled mostly as 16.3-foot logs, with a few shorter logs where necessary.
 Stump height 1 foot. Diameter inside bark of top, 6 inches.
 Data collected by T. S. Woolsey, jr., in Grafton County in 1903.

TABLE 29.—Board-foot volume of old-field red spruce in New Hampshire according to the New Hampshire rule and total height of tree.

[CURVED.]

Diameter breast high.	Total height of tree—feet.			Basis.
	40	50	60	
	Board feet.			
<i>Inches.</i>				<i>Trees.</i>
7	18	23	28	(1)
8	30	37	44	(1)
9	42	50	59	(1)
10	55	65	76	(1)
11	68	80	93	(1)
12	-----	96	111	(1)
13	-----	113	129	(1)
14	-----	129	148	(1)

¹ Impossible to give, old table.

Scaled "straight and sound" in tree lengths cutting to a diameter outside the bark of 6 inches. If logs are cut to a limit of 4 inches in the top, trees under 10 inches will scale about 10 per cent more; those over 10 inches about 1 per cent more.

Based on the measurement of 579 trees made by T. S. Woolsey, jr., in 1903.

TABLE 30.—Board-foot volume of red spruce in New York according to the Scribner Decimal C rule and total height of tree.

[CURVED.]

Diameter breast high.	Total height of tree—feet.								Basis.
	30	40	50	60	70	80	90	100	
	Volume—board feet.								
<i>Inches.</i>									<i>Trees.</i>
8	18	26	34	41	48				87
9	26	35	43	53	67	75			63
10	35	45	55	67	78	90	100		158
11	45	56	68	82	96	110	130	140	178
12	55	67	82	97	110	130	150	170	214
13		78	97	120	130	160	180	200	136
14		90	110	130	160	180	200	230	180
15		100	120	150	180	210	230	260	112
16			140	170	200	240	270	300	93
17			160	190	230	270	300	340	79
18			180	220	260	300	340	380	77
19				250	290	340	380	430	39
20				270	320	380	430	480	44
21				300	360	420	480	540	17
22				320	400	470	540	600	16
23					440	530	600	670	6
24					490	580	670	750	6
25					540	640	740	840	1
26					600	710	820	930	1
									1,507

Diameter inside bark of top, 6 inches; stump height, 1 foot. Based on taper curves; scaled mostly as 16.3-foot logs, with a few shorter logs where necessary.

Based in part on measurements taken under the direction of the Superintendent of State Forests, New York, in Essex and Herkimer Counties, 1912.

TABLE 31.—Board-foot volume of red spruce in New York according to the Scribner Decimal C rule and number of 16-foot logs.

[CURVED.]

		Number of 16-foot logs.									Basis.
Diameter breast high.		1	1½	2	2½	3	3½	4	4½	5	
		Volume—board feet.									
Inches.											Trees.
8	19	32	43	56	73	100					87
9	24	36	49	64	85	110					63
10	30	41	56	72	98	120					158
11	36	47	65	81	98	120					178
12	42	54	74	91	110	130	160				214
13		60	84	100	130	150	180				136
14		67	95	120	140	170	200	230			180
15		75	110	130	160	190	220	260			112
16			120	150	180	210	250	290			93
17			130	160	200	230	270	320			79
18			140	180	220	260	300	350	410		77
19				200	240	290	340	390	450		39
20				210	260	320	370	430	500		44
21					290	350	410	470	550		17
22					320	380	450	520	600		16
23					350	410	490	570	660		6
24					380	450	530	620	730		6
25					410	480	580	680	800		1
26					450	520	630	750	870		1
											1,507

Based on taper curves; scaled mostly as 16.3-foot logs, with a few shorter logs where necessary. Diameter inside bark of top, 6 inches; stump height, 1 foot.

Based in part on measurements taken under the direction of the Superintendent of State Forests, New York, in Essex and Herkimer Counties, 1912.

TABLE 32.—Standard volume of red spruce in New York according to the Dimick rule and total height of tree.

[CURVED.]

Diameter breast high.		Total height of tree—feet.								Basis
		30	40	50	60	70	80	90	100	
		Volume—standards. ¹								
Inches.									Trees.	
8	0.14	0.19	0.24	0.29	0.32				87	
9	.18	.24	.30	.36	.41				63	
10	.22	.29	.37	.44	.50	0.56			158	
11		.34	.44	.54	.62	.70			178	
12		.39	.52	.64	.74	.83	0.92		214	
13		.45	.60	.74	.86	.97	1.07		136	
14		.52	.69	.84	.99	1.12	1.24	1.36	180	
15			.77	.94	1.12	1.28	1.42	1.55	112	
16			.86	1.06	1.26	1.44	1.61	1.76	93	
17			.95	1.18	1.40	1.62	1.81	1.99	79	
18			1.05	1.31	1.57	1.80	2.03	2.23	77	
19				1.43	1.73	2.00	2.26	2.49	39	
20				1.55	1.90	2.22	2.51	2.78	44	
21				1.69	2.08	2.44	2.77	3.08	17	
22				1.83	2.27	2.67	3.04	3.39	16	
23					2.47	2.90	3.32	3.72	6	
24					2.66	3.14	3.61	4.06	6	
25					2.85	3.39	3.92	4.42	1	
26					3.04	3.64	4.23	4.80	1	
1,507										

¹ A Dimick standard is equal to the volume of a log 19 inches in diameter inside bark at the small end and 13 feet long. A cylinder of these dimensions contains 25.6 cubic feet.

Diameter inside bark of top, 6 inches; stump height, 1 foot. Based on taper curves; scaled mostly as 16.3-foot logs, with a few shorter logs where necessary.

Based in part on measurements taken under the direction of the Superintendent of State Forests, New York, in Essex and Herkimer Counties, 1912.

TABLE 33.—Standard volume of red spruce in New York according to the Dimick rule and number of 16-foot logs.

[CURVED.]

Diameter breast high.	Number of 16-foot logs.									Basis.
	1	1½	2	2½	3	3½	4	4½	5	
	Volume—standards. ¹									
Inches.										Trees.
8	0.14	0.22	0.29	0.37						87
9	.16	.24	.33	.42	0.47					63
10	.19	.28	.38	.47	.55	0.66				158
11	.22	.32	.43	.53	.63	.75				178
12	.26	.36	.48	.60	.72	.85	0.98			211
13		.41	.53	.66	.80	.95	1.10			136
14		.46	.59	.73	.89	1.06	1.23	1.41		180
15		.51	.65	.81	.98	1.17	1.36	1.56		112
16			.71	.89	1.08	1.29	1.50	1.71		93
17			.77	.97	1.18	1.41	1.64	1.88		79
18			.83	1.05	1.29	1.54	1.80	2.07	2.39	77
19				1.14	1.40	1.68	1.96	2.17	2.59	39
20				1.22	1.51	1.82	2.14	2.48	2.81	44
21					1.64	1.98	2.33	2.69	3.05	17
22					1.77	2.14	2.53	2.92	3.31	16
23					1.92	2.32	2.74	3.16	3.60	6
24					2.07	2.51	2.96	3.41	3.90	6
25					2.22	2.70	3.19	3.68	4.20	1
26					2.38	2.89	3.44	3.96	4.51	1
										1,507

¹ A Dimick standard is equal to the volume of a log 19 inches in diameter inside bark at the small end and 13 feet long. A cylinder of these dimensions contains 25.6 cubic feet.

Based on taper curves, scaled mostly as 16.3-foot logs, with a few shorter logs where necessary.

Diameter inside bark of top, 6 inches; stump height, 1 foot.

Based in part on measurements taken under the direction of the Superintendent of State Forests, New York, in Essex and Herkimer Counties, 1912.

TABLE 34.—Board-foot volume of red spruce in West Virginia according to the Doyle rule and total height of tree.

[CURVED.]

Diameter breast high.	Height of tree—feet.							Basis.
	50	60	70	80	90	100	110	
	Volume—board feet.							
<i>Inches.</i>								<i>Trees.</i>
8.....	5	10						2
9.....	15	20						10
10.....	25	30	30	35				19
11.....	35	40	45	50				40
12.....	45	50	60	70	80			33
13.....		70	80	90	100			42
14.....		80	100	120	130	140		38
15.....		100	130	150	160	180		29
16.....		120	150	180	200	220	240	31
17.....			180	210	240	260	290	23
18.....			210	250	280	310	350	24
19.....				280	330	370	410	16
20.....				330	380	430	470	22
21.....				380	440	490	540	18
22.....				420	500	560	610	18
23.....					560	630	690	15
24.....					620	700	770	6
25.....					680	780	860	8
26.....					760	860	960	4
27.....						940	1,040	5
28.....						1,040	1,170	6
29.....						1,140	1,290	3
30.....						1,240	1,400	1
31.....						1,340	1,530	2
32.....						1,440	1,660	
33.....						1,540	1,800	1
34.....						1,650	1,940	
								416

Based on taper curves. Logs scaled in lengths from 8 to 17 feet. Stump height, 1 foot; diameter inside bark of top, 6 inches.

Data collected by John Foley in Greenbrier County in 1903.

TABLE 35.—Board-foot volume of red spruce in West Virginia according to the Doyle rule and number of 16-foot logs.

[CURVED.]

Diameter breast high.	Number of 16-foot logs.										Basis.
	1½	2	2½	3	3½	4	4½	5	5½	6	
	Volume—board feet.										
<i>Inches.</i>											<i>Trees.</i>
8.....	5	10									2
9.....	10	15									10
10.....	15	25	30	30							19
11.....		35	40	45							40
12.....		45	50	60	70	80					33
13.....			70	80	90	100					42
14.....			80	100	110	130	150				38
15.....			100	120	140	150	180				29
16.....				140	160	180	210	240			31
17.....				160	190	220	250	280			23
18.....					220	250	280	320	360		24
19.....					250	290	330	370	410		16
20.....					290	330	370	420	480		22
21.....					330	370	420	480	540		18
22.....					360	410	470	540	610		18
23.....						460	530	600	680		15
24.....						510	590	670	760		6
25.....							660	750	820	920	8
26.....							740	820	910	1,010	4
27.....								910	1,000	1,100	5
28.....								1,000	1,090	1,190	6
29.....								1,090	1,190	1,300	3
30.....								1,180	1,290	1,410	1
31.....									1,400	1,520	2
32.....									1,520	1,640	
33.....									1,630	1,750	1
34.....									1,750	1,870	
											416

Based on taper curves. Logs scaled in lengths from 8 to 17 feet. Stump height, 1 foot; diameter inside bark of top, 6 inches.

Data collected by John Foley in Greenbrier County in 1903.

TABLE 36.—Board-foot volume of red spruce in West Virginia according to Scribner Decimal C rule and total height of tree.

[CURVED.]

Diameter breast high.	Height of tree—feet.							Basis.
	50	60	70	80	90	100	110	
	Volume—board feet.							
<i>Inches.</i>								<i>Trees.</i>
8	20	25						2
9	30	35						10
10	45	50	60	70				19
11	60	70	80	90				40
12	75	90	110	120	140			33
13		120	140	150	170			42
14		150	170	190	210	230		38
15		180	200	220	250	280		29
16		210	230	260	300	330	350	31
17			260	300	340	380	410	23
18			300	340	390	440	480	24
19				390	450	500	540	16
20				440	500	560	610	22
21				480	570	630	690	18
22				540	630	710	770	18
23					700	780	860	15
24					770	860	960	6
25					840	940	1,050	8
26					910	1,030	1,150	4
27						1,130	1,270	5
28						1,230	1,390	6
29						1,340	1,520	3
30						1,450	1,660	1
31						1,570	1,790	2
32						1,680	1,930	
33						1,790	2,060	1
34						1,910	2,200	
								416

Based on taper curves scaled as 8 and 16 foot logs. Stump height, 1 foot; diameter inside bark of top, 6 to 9 inches.

Data collected by John Foley in Greenbrier County in 1903.

TABLE 37.—Board-foot volume of red spruce in West Virginia according to Scribner Decimal C rule and number of 16-foot logs.

[CURVED.]

Diameter breast high.	Number of 16-foot logs.									Basis.	
	1½	2	2½	3	3½	4	4½	5	5½		6
	Volume—board feet.										
<i>Inches.</i>										<i>Trees.</i>	
8	25									2	
9	25	40								10	
10	30	50	70	80						19	
11		60	80	100						40	
12		80	100	120	140					33	
13			120	140	160	180				42	
14			140	170	190	220	240			38	
15			160	190	220	250	280			29	
16			190	220	250	280	320	350		31	
17				250	280	320	360	400		23	
18				280	310	360	400	450		24	
19					350	400	450	510	550	16	
20					380	440	510	570	630	22	
21					420	490	560	640	710	18	
22						530	620	710	790	18	
23							700	780	880	15	
24							770	860	970	6	
25							840	940	1,070	8	
26							910	1,030	1,160	4	
27								1,120	1,250	1,410	5
28								1,210	1,340	1,510	6
29								1,290	1,440	1,620	3
30								1,380	1,540	1,730	1
31									1,620	1,840	2
32									1,710	1,950	
33									1,810	2,060	1
34									1,910	2,180	
											416

Based on taper curves, scaled as 8 and 16 foot logs. Stump height, 1 foot; diameter inside bark of top, 6 to 9 inches.

Data collected by John Foley in Greenbrier County in 1903.

TABLE 38.—Cubic-foot volume of red spruce in Maine.

[CURVED.]

Diameter breast high.	Height of tree—feet.						Basis.
	40	50	60	70	80	90	
	Merchantable volume, including bark—cubic feet.						
<i>Inches.</i>							<i>Trees.</i>
6	3.0	4.5	5.0				5
7	5.0	6.5	7.5				8
8	7.0	9.0	10.5				11
9	9.5	11.5	13.5				18
10	12.0	14.5	17.0	18.5			29
11	14.5	17.5	20.5	22.5			21
12	17.5	21.0	24.5	27.0			27
13	21.0	25.0	28.5	31.5			20
14		29.0	33.5	36.5	40.0		22
15		33.5	38.5	42.0	46.0		13
16		38.5	43.5	48.0	52.5	57.5	11
17			49.0	54.0	59.5	65.5	14
18			54.5	60.5	67.0	73.5	19
19				67.0	74.5	82.0	6
20				74.0	82.5	91.0	6
21				81.5	91.5	101.0	6
22				89.5	100.0	111.0	4
23				97.5	109.0	122.0	4
24					118.5	133.0	
25					127.5	144.5	2
							246

Based on taper curves. Stump height, 1 foot; diameter outside bark of top, 4.5 inches.

Data collected by R. S. Hosmer in Piscataquis County in 1902.

TABLE 39.—Cubic-foot volume of red spruce, virgin and second growth,¹ in southern New Hampshire.

MERCHANTABLE VOLUME—(UNPEELED).

[CURVED.]

	Height of tree—feet.						Basis.	
Diameter breast high.	40	50	60	70	80	90	All trees.	Second- growth trees only.
	Volume—cubic feet.							
<i>Inches.</i>								
5	1.9	2.5	3.0				29	29
6	3.5	4.2	5.2	6.4			98	98
7	5.0	6.2	7.5	9.0			128	127
8	6.6	8.4	10.0	11.7			165	163
9	8.5	10.8	12.7	14.8			161	155
10		13.5	15.6	18.0			113	103
11		16.5	18.8	21.5			78	64
12		19.5	22.3	25.4			63	37
13			26.0	29.5	34.5		42	22
14			30.0	34.0	39.5		55	29
15			34.5	38.5	44.0		56	23
16			39.0	43.5	49.0		49	18
17			43.5	49.0	55.0	63.5	38	10
18			48.0	54.5	61.0	70.0	44	9
19			53.0	60.5	67.5	77.0	30	6
20			58.0	67.0	74.5	83.5	21	
21				74.0	82.0	90.5	18	
22				81.5	89.0	98.0	16	
23				88.5	96.5	105.0	10	
24				95.5	104.5	114.0	5	
25				102.0	112.0	123.0	2	
26				109.0	120.0	131.5	2	
27					128.0	140.0	2	
28					135.5	148.5	1	
							1,226	893

¹ Values within the black lines are a combination of old-growth and second-growth measurements which worked up separately gave practically identical results.

NOTE.—Stumps varying from $\frac{1}{2}$ foot to $1\frac{1}{2}$ feet high and tops above 4 inches outside bark excluded from volume.

Bark=11 per cent of volume given.

Data collected by Louis Margolin in 1906.

TABLE 40.—*Cubic-foot volume of red spruce in New York.*

[CURVED.]

		Total height of tree—feet.									
Diameter breast high.		30	40	50	60	70	80	90	100	Basis.	
		Merchantable volume, including bark—cubic feet.									
Inches.										Trees.	
6	.....	3.6	4.5	5.4	6.3						44
7	.....	4.8	6.0	7.2	8.4						40
8	.....	6.2	7.8	9.3	10.9	12.4					87
9	.....	7.7	9.7	11.6	13.5	15.5					63
10	.....	9.5	12.0	14.3	16.8	19.2	21.5				158
11	.....		14.4	17.2	20.0	23.0	26.0				178
12	.....		17.1	20.5	24.0	27.5	31.0	34.5			214
13	.....		19.9	23.5	27.5	32.0	36.0	40.0			136
14	.....		23.0	27.5	32.0	37.0	41.5	46.0		51	180
15	.....			31.5	37.0	42.0	47.5	53.0		58	112
16	.....			35.5	41.5	48.0	54.0	60.0		66	93
17	.....			40.0	47.0	54.0	61.0	68.0		74	79
18	.....			44.5	52.0	60.0	68.0	76.0		83	77
19	.....				58.0	67.0	75.0	84.0		92	39
20	.....				64.0	74.0	83.0	93.0		102	44
21	.....				71.0	81.0	92.0	102.0		113	17
22	.....				77.0	89.0	101.0	112.0		123	16
23	.....					97.0	110.0	123.0		135	6
24	.....					106.0	119.0	133.0		146	6
25	.....					114.0	130.0	145.0		159	1
26	.....					124.0	140.0	156.0		172	1
											1,591

Stump height, 1 foot; top diameter outside bark, 4.5 inches. Based on taper curves.

Based in part on measurements taken under the direction of the Superintendent of State Forests, New York, in Essex and Herkimer Counties, 1912.

TABLE 41.—*Cubic-foot volume of red spruce in West Virginia.*

[CURVED.]

Diameter breast high.	Height of tree—feet.							Basis.
	50	60	70	80	90	100	110	
	Merchantable volume, including bark—cubic feet.							
<i>Inches.</i>								<i>Trees.</i>
6.....	3.5							1
7.....	6.0							2
8.....	8.5	10.0						10
9.....	11.0	13.0						19
10.....	14.0	16.0	18.5	20.5				40
11.....	17.0	19.5	22.5	24.5				33
12.....	20.0	23.5	26.5	29.5	32.5			42
13.....		27.5	31.0	34.5	38.0			38
14.....		32.0	36.0	40.0	44.5	48.0		29
15.....		36.5	41.5	45.5	51.0	56.0		31
16.....		41.5	47.0	52.0	58.5	64.0	69.5	23
17.....			52.5	58.5	66.0	72.5	78.5	24
18.....			58.0	66.0	74.0	81.0	88.0	16
19.....				73.0	82.0	90.0	98.0	22
20.....				81.0	91.0	100.0	108.5	18
21.....				88.5	100.0	110.5	120.0	18
22.....				97.0	110.0	121.5	132.0	15
23.....					120.0	132.5	144.5	6
24.....					130.5	144.0	157.5	8
25.....					141.0	156.5	171.0	4
26.....					152.0	169.0	185.5	5
27.....						182.0	200.5	6
28.....						195.0	216.0	3
29.....						209.0	232.0	1
30.....						223.0	249.0	2
31.....						237.5	265.5	1
32.....						252.5	283.0	
33.....						268.5	302.0	
34.....						284.5	321.0	
								417

Based on taper curves. Stump height, 1 foot; diameter outside bark of top, 4.5 inches.

Data collected by John Foley in Greenbrier County in 1903.

TABLE 42.—*Cordwood volume of red spruce (old-field) in New Hampshire, bark included.*

[CURVED.]

Diameter breast high.	Height of tree—feet.				
	40	50	60	70	80
	Volume—cords. ¹				
<i>Inches.</i>					
6	0.028	0.032	0.041		
7	.048	.053	.070		
8	.070	.084	.099		
9	.093	.110	.129	0.155	
10	.115	.137	.160	.185	
11		.164	.190	.217	
12		.192	.220	.250	
13			.252	.282	0.314
14			.284	.315	.349
15			.316	.348	.384
16			.348	.381	.419
17			.380	.414	.455
18			.411	.447	.490

¹ Includes bark.

Top diameter outside bark, 5 inches. Based on 711 trees, measured by T. S. Woolsey, jr., in Grafton County in 1911.

One cord of stacked wood equals 96 cubic feet of solid wood and bark.

TABLE 43.—*Cordwood volume of red spruce (old-field) in New Hampshire, bark included.*

Diameter breast high.	Trees 40 feet high.				Trees 50 feet high.			
	Volume cutting to—		Trees per cord, cutting to—		Volume cutting to—		Trees per cord, cutting to—	
	6 inches.	4 inches.	6 inches.	4 inches.	6 inches.	4 inches.	6 inches.	4 inches.
<i>Inches.</i>	<i>Cord.</i>	<i>Cord.</i>			<i>Cord.</i>	<i>Cord.</i>		
6				25.6				22.2
7	0.033	.060	30.3	16.6	0.043	.069	23.2	14.5
8					.071	.093	14.1	10.7
9					.100	.120	10.0	8.3
10					.129	.144	7.7	6.9
11					.159	.170	6.2	5.8
	Trees 60 feet high.				Trees 70 feet high.			
6		0.052		19.2				
7	0.051	.083	19.6	12.0				
8	.088	.112	11.3	8.9				
9	.120	.139	8.3	7.2	0.150	0.162	6.6	6.1
10	.150	.168	6.6	5.9	.190	.198	5.5	5.2
11	.179	.199	5.6	5.0	.211	.220	4.7	4.5
12	.212	.230	4.7	4.3	.243	.256	4.1	3.9
13	.245	.263	4.1	3.8	.266	.289	3.7	3.5
14	.279	.294	3.5	3.4	.310	.322	3.2	3.1

Basis, 711 trees measured by T. S. Woolsey, jr., in Grafton County in 1903.

One cord of stacked wood equals 96 cubic feet of solid wood and bark.

TABLE 44.—*Cordwood volume of red spruce (old-field) in New Hampshire, bark excluded.*

Diameter breast high.	Trees 40 feet high.				Trees 50 feet high.			
	Volume cutting to—		Trees per cord, cutting to—		Volume cutting to—		Trees per cord, cutting to—	
	6 inches.	4 inches.	6 inches.	4 inches.	6 inches.	4 inches.	6 inches.	4 inches.
<i>Inches.</i>	<i>Cord.</i>	<i>Cord.</i>			<i>Cord.</i>	<i>Cord.</i>		
6		0.032		31.2		0.040		25.0
7	0.028	.051	35.7	19.6	0.038	.061	26.3	16.4
8					.065	.081	15.4	12.3
9					.088	.102	11.3	9.8
10					.113	.125	8.8	8.0
11					.137	.150	7.3	6.6
Trees 60 feet high.					Trees 70 feet high.			
6		0.047		21.3				
7	0.046	.074	21.7	13.5				
8	.077	.160	12.9	10.0				
9	.108	.123	9.2	8.1	0.133	0.142	7.5	7.0
10	.136	.146	7.2	6.8	.162	.171	6.2	5.8
11	.161	.173	6.2	5.7	.190	.199	5.2	5.0
12	.186	.199	5.3	5.0	.218	.229	4.5	4.3
13	.213	.226	4.7	4.4	.247	.258	4.0	3.8
14	.243	.255	4.1	3.5	.277	.289	3.6	3.4

Basis, 711 trees measured by T. S. Woolsey, jr., in Grafton County in 1903.
One cord of stacked wood equals 96 cubic feet of solid wood and bark.

TAPER MEASUREMENTS.

Changing economic conditions, due to invention, increasing demand, and decreasing supply, cause corresponding changes in logging practice and mill utilization. It is essential that we have some means readily available by which volume and other tables may be revised or new ones made as these changes take place. Taper tables afford such a means by showing for each 10-foot height class and each 1-inch diameter class (breastheight diameter measured outside the bark), the diameter inside the bark at 1-foot intervals from the ground up to 4.5 feet (breastheight), and at 8.15-foot intervals above a 1-foot stump height. The allowance of 0.15 of a foot at each 8-foot section is for loss in trimming at the mill. The taper tables (Tables 45 to 49) for each of the four States are all for "old-growth" spruce, except Table 46, which is for "second-growth" or "old-field" spruce.

TABLE 45.—*Taper measurements (diameter inside bark) of red spruce in Maine.*

40-FOOT TREES.														[CURVED.]
Diameter breast high.	Height above ground—feet.													Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	
	Diameter inside bark—inches.													
Inches.														Trees.
6.....	7.6	7.0	6.2	5.5	4.9	4.3	3.4							4
7.....	8.8	8.1	7.3	6.4	5.9	5.2	4.1							5
8.....	9.9	9.2	8.4	7.4	6.8	6.0	4.7							3
9.....	11.0	10.2	9.5	8.4	7.8	6.9	5.5							6
10.....	12.2	11.3	10.6	9.3	8.6	7.7	6.2							5
11.....	13.3	12.4	11.6	10.3	9.5	8.5	6.9							5
12.....	14.4	13.5	12.7	11.3	10.4	9.4	7.6							2
13.....	15.6	14.6	13.7	12.2	11.4	10.3	8.3							1
14.....	16.7	15.6	14.7	13.2	12.4	11.2	9.1							31
50-FOOT TREES.														
6.....	7.6	7.0	6.2	5.5	5.2	4.7	4.2	3.3						2
7.....	8.8	8.1	7.3	6.4	6.0	5.5	4.9	3.9						8
8.....	9.9	9.2	8.4	7.4	6.9	6.3	5.7	4.5						7
9.....	11.0	10.2	9.5	8.4	7.8	7.1	6.4	5.1						7
10.....	12.2	11.3	10.6	9.3	8.7	8.0	7.1	5.7						10
11.....	13.3	12.4	11.6	10.3	9.6	8.8	7.9	6.3						7
12.....	14.4	13.5	12.7	11.3	10.5	9.6	8.6	6.9						7
13.....	15.6	14.6	13.7	12.2	11.5	10.5	9.4	7.6						5
14.....	16.7	15.6	14.7	13.2	12.4	11.1	10.2	8.2						1
15.....	17.9	16.7	15.8	14.1	13.3	12.1	11.0	8.8						1
16.....	19.0	17.8	16.8	15.1	14.2	12.8	11.7	9.4						48
60-FOOT TREES.														
6.....	7.6	7.0	6.2	5.5	5.0	4.7	4.4	3.9	3.0	1.8				1
7.....	8.8	8.1	7.3	6.4	6.0	5.6	5.2	4.6	3.5	2.1				1
8.....	9.9	9.2	8.4	7.4	7.0	6.5	5.9	5.1	4.1	2.5				5
9.....	11.0	10.2	9.5	8.4	7.9	7.3	6.7	5.9	4.7	2.8				9
10.....	12.2	11.3	10.6	9.3	8.8	8.1	7.5	6.6	5.2	3.1				7
11.....	13.3	12.4	11.6	10.3	9.8	9.0	8.2	7.2	5.7	3.5				9
12.....	14.4	13.5	12.7	11.3	10.7	9.8	9.0	8.0	6.2	3.7				11
13.....	15.6	14.6	13.7	12.2	11.6	10.6	9.8	8.6	6.8	4.1				11
14.....	16.7	15.6	14.7	13.2	12.5	11.4	10.5	9.3	7.3	4.4				8
15.....	17.9	16.7	15.8	14.1	13.4	12.2	11.3	10.0	7.8	4.7				1
16.....	19.0	17.8	16.8	15.1	14.3	13.0	12.1	10.6	8.2	5.0				1
17.....	20.3	19.0	17.8	16.0	15.1	13.8	12.8	11.3	8.8	5.3				1
18.....	21.5	20.2	18.9	17.0	16.1	14.6	13.5	12.0	9.3	5.5				64
70-FOOT TREES.														
10.....	12.2	11.3	10.6	9.3	8.8	8.1	7.7	7.1	6.0	4.4	2.6			5
11.....	13.3	12.4	11.6	10.3	9.7	8.9	8.4	7.7	6.6	4.9	2.9			2
12.....	14.4	13.5	12.7	11.3	10.7	9.8	9.1	8.4	7.2	5.5	3.2			11
13.....	15.6	14.6	13.7	12.2	11.5	10.6	9.9	9.0	7.8	5.9	3.5			2
14.....	16.7	15.6	14.7	13.2	12.5	11.5	10.6	9.6	8.3	6.4	3.8			6
15.....	17.9	16.7	15.8	14.1	13.4	12.3	11.4	10.4	9.0	6.8	4.2			3
16.....	19.0	17.8	16.8	15.1	14.3	13.1	12.1	11.1	9.5	7.3	4.5			5
17.....	20.3	19.0	17.8	16.0	15.3	14.0	12.9	11.8	10.1	7.8	4.8			8
18.....	21.5	20.2	18.9	17.0	16.2	14.8	13.6	12.4	10.6	8.2	5.0			7
19.....	22.8	21.3	20.0	18.0	17.1	15.6	14.3	13.0	11.2	8.7	5.4			1
20.....	24.1	22.5	21.1	18.9	18.0	16.4	15.0	13.7	11.8	9.1	5.6			3
21.....	25.3	23.6	22.2	19.9	18.8	17.2	15.9	14.3	12.3	9.6	6.0			1
22.....	26.6	24.8	23.3	20.9	19.8	18.0	16.6	15.0	12.9	10.0	6.3			1
23.....	27.9	26.0	24.4	21.9	20.7	18.9	17.3	15.6	13.4	10.5	6.6			55

TABLE 45.—*Taper measurements (diameter inside bark) of red spruce in Maine—Contd.*

80-FOOT TREES.

[CURVED.]

Diameter breast high.	Height above ground—feet.													Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	
	Diameter inside bark—inches.													
<i>Inches.</i>	16.7	15.6	14.7	13.2	12.4	11.4	10.6	9.8	8.8	7.4	5.6	3.6	-----	<i>Trees.</i>
14.....	17.9	16.7	15.8	14.1	13.4	12.3	11.5	10.6	9.5	7.9	6.1	3.9	-----	3
15.....	19.0	17.8	16.8	15.1	14.3	13.1	12.2	11.2	10.1	8.5	6.6	4.2	-----	2
16.....	20.3	19.0	17.8	16.0	15.1	14.0	13.1	12.1	10.8	9.1	7.0	4.5	-----	4
17.....	21.5	20.2	18.9	17.0	16.1	14.8	13.8	12.8	11.5	9.7	7.5	4.8	-----	5
18.....	22.8	21.3	20.0	18.0	17.2	15.8	14.6	13.5	12.2	10.4	8.0	5.1	-----	11
19.....	24.1	22.5	21.1	18.9	18.0	16.6	15.4	14.2	12.9	11.0	8.4	5.4	-----	2
20.....	25.3	23.6	22.2	19.9	18.9	17.5	16.2	15.0	13.5	11.5	8.9	5.8	-----	2
21.....	26.6	24.8	23.3	20.9	19.9	18.3	17.0	15.7	14.1	12.0	9.3	6.1	-----	3
22.....	27.9	26.0	24.4	21.9	20.8	19.1	17.8	16.4	14.8	12.6	9.7	6.4	-----	2
23.....	29.3	27.2	25.5	22.8	21.7	19.9	18.4	17.0	15.4	13.1	10.2	6.7	-----	3
24.....	30.6	28.5	26.6	23.8	22.6	20.7	19.2	17.7	16.0	13.7	10.6	6.9	-----	1
25.....													-----	38
90-FOOT TREES.														
16.....	19.0	17.8	16.8	15.1	14.2	13.1	12.1	11.4	10.6	9.5	8.0	6.2	4.1	-----
17.....	20.3	19.0	17.8	16.0	15.1	14.0	13.0	12.3	11.4	10.2	8.6	6.5	4.3	-----
18.....	21.5	20.2	18.9	17.0	16.1	14.9	13.9	13.0	12.1	10.8	9.0	7.0	4.6	1
19.....	22.8	21.3	20.0	18.0	17.1	15.8	14.7	13.8	12.7	11.4	9.6	7.4	4.9	4
20.....	24.1	22.5	21.1	18.9	18.1	16.8	15.6	14.6	13.4	12.0	10.1	7.8	5.1	3
21.....	25.3	23.6	22.2	19.9	19.0	17.7	16.5	15.4	14.2	12.7	10.6	8.2	5.4	-----
22.....	26.6	24.8	23.3	20.9	20.0	18.7	17.3	16.1	14.9	13.2	11.1	8.6	5.7	1
23.....	27.9	26.0	24.4	21.9	21.0	19.5	18.2	17.0	15.6	13.9	11.8	9.1	6.0	-----
24.....	29.3	27.2	25.5	22.8	22.0	20.5	19.0	17.7	16.3	14.5	12.3	9.4	6.2	-----
25.....	30.6	28.5	26.6	23.8	22.9	21.4	19.8	18.5	17.1	15.2	12.9	9.9	6.5	1
														10

Data collected by R. S. Hosmer in Piscataquis County in 1902.

TABLE 46.—*Taper measurements (diameter inside bark) of red spruce (old-field) in New Hampshire.*

40-FOOT TREES.											[CURVED.]
Diam- eter breast high.	Height above ground—feet.										Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	
	Diameter inside bark—inches.										
<i>Inches.</i>	5.6	5.3	5.0	4.7	4.2	3.6	2.9				<i>Trees.</i>
5.....	5.6	5.3	5.0	4.7	4.2	3.6	2.9				4
6.....	6.7	6.3	6.0	5.6	5.1	4.4	3.5				9
7.....	7.8	7.4	7.0	6.6	6.0	5.2	4.1				8
8.....	9.0	8.4	8.0	7.5	6.9	6.0	4.7				2
9.....	10.1	9.5	9.1	8.4	7.7	6.7	5.3				
10.....	11.3	10.6	10.1	9.4	8.6	7.6	5.9				2
11.....	12.4	11.7	11.1	10.4	9.5	8.3	6.5				1
12.....	13.6	12.8	12.2	11.4	10.4	9.0	7.0				26
50-FOOT TREES.											
5.....	5.6	5.3	5.0	4.7	4.5	4.0	3.5	2.6			2
6.....	6.7	6.3	6.0	5.6	5.4	4.9	4.2	3.1			15
7.....	7.8	7.4	7.0	6.6	6.2	5.6	4.8	3.6			23
8.....	9.0	8.4	8.0	7.5	7.1	6.4	5.5	4.1			9
9.....	10.1	9.5	9.1	8.4	7.9	7.2	6.2	4.6			15
10.....	11.3	10.6	10.1	9.4	8.8	8.0	6.9	5.1			5
11.....	12.4	11.7	11.1	10.4	9.6	8.7	7.5	5.6			2
12.....	13.6	12.8	12.2	11.4	10.5	9.4	8.2	6.0			71
60-FOOT TREES.											
7.....	7.8	7.4	7.0	6.6	6.2	5.6	5.1	4.3	3.2		2
8.....	9.0	8.4	8.0	7.5	7.1	6.5	5.8	4.9	3.7		5
9.....	10.1	9.5	9.1	8.4	8.0	7.4	6.6	5.6	4.2		3
10.....	11.3	10.6	10.1	9.4	8.9	8.2	7.4	6.2	4.7		2
11.....	12.4	11.7	11.1	10.4	9.8	9.0	8.1	6.8	5.2		3
12.....	13.6	12.8	12.2	11.4	10.7	9.8	8.8	7.5	5.7		3
13.....	14.8	13.9	13.2	12.4	11.6	10.6	9.6	8.1	6.1		1
14.....	16.0	15.0	14.3	13.4	12.5	11.4	10.3	8.7	6.6		1
15.....	17.3	16.2	15.4	14.4	13.4	12.2	11.0	9.3	7.1		1
16.....	18.6	17.3	16.5	15.4	14.2	13.0	11.7	10.0	7.6		21
70-FOOT TREES.											
8.....	9.0	8.4	8.0	7.5	7.1	6.6	6.1	5.4	4.4	3.1	
9.....	10.1	9.5	9.1	8.4	8.0	7.5	6.9	6.0	4.9	3.5	
10.....	11.3	10.6	10.1	9.4	9.0	8.4	7.7	6.8	5.5	3.9	
11.....	12.4	11.7	11.1	10.4	9.9	9.2	8.5	7.4	6.0	4.3	
12.....	13.6	12.8	12.2	11.4	10.8	10.0	9.2	8.0	6.6	4.7	1
13.....	14.8	13.9	13.2	12.4	11.8	10.9	9.9	8.7	7.1	5.1	
14.....	16.0	15.0	14.3	13.4	12.7	11.7	10.7	9.4	7.6	5.5	
15.....	17.3	16.2	15.4	14.4	13.7	12.6	11.5	10.0	8.1	5.8	1
16.....	18.6	17.3	16.5	15.4	14.6	13.5	12.3	10.7	8.7	6.2	
17.....	19.8	18.5	17.6	16.4	15.5	14.3	13.0	11.4	9.2	6.5	
18.....	21.1	19.6	18.8	17.4	16.4	15.1	13.8	12.1	9.8	6.9	1
											3

Data collected by T. S. Woolsey, jr., in Grafton County in 1903.

TABLE 47.—*Taper measurements (diameter inside bark) of red spruce (old-growth) in New Hampshire.*

60-FOOT TREES.

Diameter breast high.	Height above ground—feet.												Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	
	Diameter inside bark—inches.												
<i>Inches.</i>													<i>Trees.</i>
6.....	6.5	6.0	5.7	5.5	5.4	5.1	4.9	4.5	3.8	2.6	.....	.....	1
7.....	7.7	7.1	6.7	6.5	6.2	5.9	5.5	5.0	4.2	2.9	.....	.....	1
8.....	8.8	8.2	7.8	7.5	7.1	6.6	6.2	5.6	4.6	3.2	.....	.....	6
9.....	9.9	9.3	8.8	8.4	8.0	7.4	6.8	6.1	5.1	3.5	.....	.....	16
10.....	11.1	10.4	9.9	9.4	8.9	8.2	7.5	6.7	5.5	3.8	.....	.....	29
11.....	12.3	11.5	11.0	10.4	9.8	8.9	8.2	7.3	5.9	4.1	.....	.....	41
12.....	13.4	12.6	12.1	11.4	10.7	9.7	8.9	7.9	6.4	4.4	.....	.....	47
13.....	14.6	13.7	13.1	12.4	11.5	10.5	9.6	8.4	6.8	4.6	.....	.....	27
14.....	15.7	14.8	14.2	13.4	12.4	11.2	10.3	9.0	7.3	4.9	.....	.....	37
15.....	16.9	15.9	15.3	14.3	13.2	12.0	10.9	9.6	7.7	5.2	.....	.....	15
16.....	18.0	17.0	16.3	15.3	14.0	12.7	11.6	10.2	8.2	5.5	.....	.....	17
17.....	19.1	18.1	17.3	16.3	14.8	13.5	12.3	10.8	8.7	5.8	.....	.....	9
18.....	20.3	19.1	18.4	17.2	15.7	14.3	13.0	11.4	9.2	6.1	.....	.....	4
19.....	21.3	20.2	19.4	18.2	16.5	15.0	13.7	11.9	9.6	6.4	.....	.....	1
20.....	22.4	21.3	20.4	19.2	17.4	15.8	14.4	12.5	10.0	6.7	.....	.....	4
21.....	23.5	22.4	21.4	20.1	18.2	16.5	15.0	13.0	10.4	6.9	.....	.....	
22.....	24.6	23.4	22.4	21.1	19.1	17.2	15.7	13.6	10.8	7.2	.....	.....	
23.....	25.7	24.4	23.3	22.1	19.8	18.0	16.3	14.1	11.2	7.4	.....	.....	
24.....	26.8	25.5	24.3	23.1	20.6	18.7	17.0	14.6	11.6	7.7	.....	.....	
25.....	27.8	26.5	25.3	24.0	21.5	19.4	17.6	15.1	12.0	7.9	.....	.....	
26.....	28.9	27.5	26.2	25.0	22.3	20.1	18.3	15.7	12.4	8.2	.....	.....	1
													256

70-FOOT TREES.

8.....	8.8	8.2	7.8	7.5	7.2	6.8	6.4	5.9	5.1	4.1	2.9	.....	.....
9.....	9.9	9.3	8.8	8.4	8.1	7.5	7.1	6.5	5.6	4.5	3.2	.....	1
10.....	11.1	10.4	9.9	9.4	9.0	8.3	7.8	7.1	6.1	4.9	3.4	.....	1
11.....	12.3	11.5	11.0	10.4	9.8	9.1	8.5	7.7	6.7	5.3	3.6	.....	4
12.....	13.4	12.6	12.1	11.4	10.7	9.8	9.2	8.4	7.3	5.8	3.9	.....	23
13.....	14.6	13.7	13.1	12.4	11.5	10.6	9.9	9.0	7.8	6.2	4.2	.....	13
14.....	15.7	14.8	14.2	13.3	12.4	11.4	10.6	9.7	8.4	6.6	4.4	.....	22
15.....	16.9	15.9	15.3	14.3	13.2	12.2	11.3	10.3	8.9	7.0	4.7	.....	15
16.....	18.0	17.0	16.3	15.3	14.1	13.0	12.1	11.0	9.5	7.5	4.9	.....	15
17.....	19.1	18.1	17.3	16.3	15.0	13.8	12.8	11.6	10.1	7.9	5.1	.....	8
18.....	20.3	19.1	18.4	17.2	15.9	14.5	13.6	12.3	10.7	8.4	5.4	.....	9
19.....	21.3	20.2	19.4	18.2	16.7	15.3	14.3	12.9	11.2	8.8	5.6	.....	8
20.....	22.4	21.3	20.4	19.2	17.6	16.0	15.0	13.5	11.7	9.2	5.9	.....	3
21.....	23.5	22.4	21.4	20.1	18.4	16.8	15.7	14.1	12.3	9.6	6.1	.....	.....
22.....	24.6	23.4	22.4	21.1	19.3	17.6	16.4	14.8	12.8	10.0	6.4	.....	1
23.....	25.7	24.4	23.3	22.1	20.2	18.4	17.1	15.4	13.4	10.5	6.7	.....	.....
24.....	26.8	25.5	24.3	23.1	21.0	19.1	17.8	16.0	13.9	10.9	7.0	.....	.....
25.....	27.8	26.5	25.3	24.0	21.9	19.9	18.4	16.7	14.5	11.3	7.3	.....	.....
26.....	28.9	27.5	26.2	25.0	22.7	20.5	19.1	17.3	15.0	11.7	7.6	.....	.....
													123

80-FOOT TREES.

10.....	11.1	10.4	9.9	9.4	9.0	8.4	7.8	7.2	6.4	5.4	4.4	2.9	.....
11.....	12.3	11.5	11.0	10.4	9.8	9.1	8.5	7.9	7.0	5.9	4.8	3.2	.....
12.....	13.4	12.6	12.1	11.4	10.7	9.9	9.3	8.6	7.6	6.4	5.2	3.5	1
13.....	14.6	13.7	13.1	12.4	11.6	10.7	10.0	9.3	8.3	7.0	5.6	3.8	1
14.....	15.7	14.8	14.2	13.3	12.5	11.5	10.8	10.0	8.9	7.6	6.0	4.1	2
15.....	16.9	15.9	15.3	14.3	13.3	12.3	11.5	10.7	9.5	8.1	6.4	4.3	2
16.....	18.0	17.0	16.3	15.3	14.2	13.1	12.3	11.4	10.2	8.6	6.8	4.6	2
17.....	19.1	18.1	17.3	16.3	15.1	13.9	13.0	12.1	10.8	9.1	7.2	4.9	5
18.....	20.3	19.1	18.4	17.2	16.0	14.7	13.8	12.8	11.5	9.6	7.6	5.2	8
19.....	21.3	20.2	19.4	18.2	16.9	15.5	14.6	13.5	12.1	10.1	8.0	5.4	4
20.....	22.4	21.3	20.4	19.2	17.8	16.3	15.3	14.2	12.7	10.6	8.4	5.6	2
21.....	23.5	22.4	21.4	20.1	18.6	17.1	16.1	14.9	13.3	11.1	8.7	5.8	2
22.....	24.6	23.4	22.4	21.1	19.5	17.9	16.8	15.6	13.9	11.7	9.1	6.1	.....
23.....	25.7	24.4	23.3	22.1	20.3	18.7	17.6	16.3	14.5	12.3	9.5	6.4	.....
24.....	26.8	25.5	24.3	23.1	21.2	19.5	18.4	16.9	15.1	12.8	9.9	6.6	.....
25.....	27.8	26.5	25.3	24.0	22.1	20.3	19.1	17.6	15.7	13.3	10.3	6.8	.....
26.....	28.9	27.5	26.2	25.0	23.0	21.2	19.9	18.3	16.3	13.9	10.7	7.0	2
													33

TABLE 48.—Taper measurements (diameter inside bark) of red spruce in New York.

30-FOOT TREES.

[CURVED.]

[illegible]

40-FOOT TREES.

[illegible]

50-FOOT TREES.

[illegible]

60-FOOT TREES.

[illegible]

TABLE 48.—*Taper measurements (diameter inside bark) of red spruce in New York—Contd.*

90-FOOT TREES.

Diameter at breast high.	Height above ground—Feet.														Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	
	Diameter inside bark—Inches.														
<i>Inches.</i>	12... 13... 14... 15... 16... 17... 18... 19... 20... 21... 22... 23... 24... 25... 26...	13.9 15.1 16.2 17.4 18.7 20.0 21.3 22.7 24.1 25.5 26.9 28.4 29.8 31.2 32.7	13.0 14.1 15.2 16.4 17.5 18.7 19.8 21.0 22.3 23.5 24.8 26.0 27.3 28.6 29.9	12.3 13.3 14.4 15.5 16.6 17.6 18.7 19.8 20.9 22.0 23.1 24.2 25.4 26.6 27.8	11.3 12.2 13.2 14.2 15.1 16.0 17.0 18.0 18.9 19.8 20.8 21.7 22.7 23.6 24.6	10.7 11.5 12.3 13.2 14.0 14.8 15.6 16.5 17.2 18.0 18.8 19.7 20.5 21.4 22.2	10.1 10.9 11.7 12.5 13.3 14.1 14.9 15.7 16.5 17.3 18.2 19.1 19.8 20.5 21.4	9.6 10.4 11.2 12.0 12.7 13.6 14.3 15.1 15.8 16.6 17.3 18.1 18.9 19.7 20.4	9.0 9.8 10.5 11.3 12.0 12.7 13.5 14.2 14.9 15.6 16.3 17.1 17.8 18.6 19.3	8.2 8.9 9.6 10.3 10.9 11.6 12.4 13.1 13.7 14.4 15.1 15.9 16.5 17.2 18.0	7.3 7.9 8.5 9.2 9.8 10.4 11.1 11.7 12.3 12.9 13.6 14.2 14.8 15.5 16.1	6.2 6.8 7.3 7.9 8.5 9.0 9.6 10.1 10.6 11.2 11.7 12.3 12.9 13.4 14.0 14.6	4.9 5.4 5.8 6.3 6.8 7.2 7.7 8.1 8.5 9.0 9.4 9.9 10.4 10.8 11.3	3.4 3.7 4.1 4.4 4.8 5.1 5.4 5.7 6.0 6.4 6.7 7.0 7.4 7.7 8.0	<i>Trees.</i> ----- 1 ----- 3 ----- 1 ----- 11 ----- 16 ----- 15 ----- 8 ----- 5 ----- 13 ----- 2 ----- 1 ----- 79

100-FOOT TREES.

14...	16.2	15.2	14.4	13.2	12.3	11.8	11.3	10.7	9.8	8.7	7.6	6.3	4.8	3.3	-----
15...	17.4	16.4	15.5	14.2	13.1	12.6	12.1	11.4	10.4	9.4	8.2	6.9	5.3	3.7	-----
16...	18.7	17.5	16.6	15.1	13.9	13.4	12.8	12.2	11.2	10.1	8.8	7.4	5.8	4.1	-----
17...	20.0	18.7	17.6	16.0	14.7	14.2	13.6	12.8	11.9	10.8	9.5	8.0	6.3	4.4	1
18...	21.3	19.8	18.7	17.0	15.5	15.0	14.3	13.6	12.7	11.5	10.3	8.6	6.8	4.7	2
19...	22.7	21.0	19.8	18.0	16.4	15.8	15.1	14.4	13.4	12.2	10.9	9.2	7.3	5.1	1
20...	24.1	22.3	20.9	18.9	17.2	16.6	15.9	15.1	14.1	12.9	11.5	9.8	7.8	5.6	2
21...	25.5	23.5	22.0	19.8	18.1	17.4	16.7	15.9	14.8	13.6	12.2	10.4	8.3	5.9	-----
22...	26.9	24.8	23.1	20.8	19.0	18.3	17.5	16.7	15.6	14.3	12.8	10.9	8.8	6.3	-----
23...	28.4	26.0	24.2	21.7	19.9	19.1	18.3	17.4	16.3	15.0	13.5	11.6	9.3	6.7	1
24...	29.8	27.3	25.4	22.7	20.8	20.0	19.1	18.2	17.1	15.8	14.2	12.2	9.8	7.1	1
25...	31.2	28.6	26.6	23.6	21.7	20.8	19.9	18.9	17.8	16.4	14.9	12.9	10.4	7.5	1
26...	32.7	29.9	27.8	24.6	22.6	21.6	20.7	19.7	18.5	17.2	15.6	13.4	10.8	7.9	1
															10

Data collected in part under the supervision of the Superintendent of State Forests in Essex and Herkimer Counties in 1912.

TABLE 49.—*Taper measurements (diameter inside bark) of red spruce in West Virginia.*

50-FOOT TREES.

[CURVED.]

Diameter breast high.	Height above ground—Feet.																Basis.
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.95	98.8	
	Diameter inside bark—Inches.																
<i>Inches.</i>																	<i>Trees.</i>
6.....	7.1	6.6	6.2	5.7	5.3	4.8	4.3	3.6	.....	.....	.....	.....	.....	.....	.....	.....	1
7.....	8.1	7.5	7.1	6.7	6.2	5.6	5.0	4.1	.....	.....	.....	.....	.....	.....	.....	.....	2
8.....	9.2	8.5	8.1	7.7	7.1	6.4	5.7	4.7	.....	.....	.....	.....	.....	.....	.....	.....	7
9.....	10.2	9.5	9.1	8.6	8.0	7.2	6.3	5.3	.....	.....	.....	.....	.....	.....	.....	.....	1
10.....	11.2	10.5	10.1	9.6	8.9	8.0	7.0	5.8	.....	.....	.....	.....	.....	.....	.....	.....	2
11.....	12.2	11.5	11.1	10.5	9.9	8.9	7.7	6.4	.....	.....	.....	.....	.....	.....	.....	.....	.....
12.....	13.3	12.6	12.1	11.5	10.8	9.6	8.4	7.0	.....	.....	.....	.....	.....	.....	.....	.....	13

60-FOOT TREES.

8.....	9.2	8.5	8.1	7.7	7.2	6.6	5.9	5.2	4.2	2.8	.....	.....	.....	.....	.....	.....	3
9.....	10.2	9.5	9.1	8.6	8.1	7.4	6.7	5.9	4.7	3.1	.....	.....	.....	.....	.....	.....	10
10.....	11.2	10.5	10.1	9.6	9.1	8.2	7.4	6.6	5.3	3.4	.....	.....	.....	.....	.....	.....	13
11.....	12.2	11.5	11.1	10.5	9.9	9.0	8.1	7.2	5.9	3.8	.....	.....	.....	.....	.....	.....	6
12.....	13.3	12.6	12.1	11.5	10.8	9.8	8.9	7.9	6.4	4.1	.....	.....	.....	.....	.....	.....	4
13.....	14.4	13.6	13.1	12.5	11.7	10.6	9.7	8.6	7.0	4.5	.....	.....	.....	.....	.....	.....	.....
14.....	15.5	14.6	14.1	13.4	12.6	11.4	10.3	9.2	7.6	4.9	.....	.....	.....	.....	.....	.....	1
15.....	16.6	15.7	15.1	14.4	13.5	12.2	11.1	9.9	8.1	5.2	.....	.....	.....	.....	.....	.....	37
16.....	17.7	16.8	16.2	15.4	14.4	13.0	11.8	10.5	8.6	5.5	.....	.....	.....	.....	.....	.....	.....

70-FOOT TREES.

10.....	11.2	10.5	10.1	9.6	9.0	8.3	7.7	6.9	6.1	5.0	3.5	.....	.....	.....	.....	.....	5
11.....	12.2	11.5	11.1	10.5	10.0	9.2	8.4	7.6	6.7	5.5	3.7	.....	.....	.....	.....	.....	23
12.....	13.3	12.6	12.1	11.5	10.9	10.0	9.2	8.3	7.3	5.9	4.0	.....	.....	.....	.....	.....	21
13.....	14.4	13.6	13.1	12.5	11.7	10.8	9.9	9.0	7.9	6.3	4.2	.....	.....	.....	.....	.....	15
14.....	15.5	14.6	14.1	13.4	12.6	11.6	10.7	9.7	8.5	6.9	4.5	.....	.....	.....	.....	.....	12
15.....	16.6	15.7	15.1	14.4	13.5	12.4	11.5	10.4	9.1	7.3	4.8	.....	.....	.....	.....	.....	7
16.....	17.7	16.8	16.2	15.4	14.4	13.2	12.2	11.1	9.7	7.8	5.1	.....	.....	.....	.....	.....	2
17.....	18.8	17.8	17.2	16.3	15.3	14.0	12.9	11.7	10.3	8.2	5.3	.....	.....	.....	.....	.....	.....
18.....	20.0	18.9	18.2	17.3	16.2	14.8	13.6	12.4	10.8	8.6	5.6	.....	.....	.....	.....	.....	1
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	86

80-FOOT TREES.

10.....	11.2	10.5	10.1	9.6	9.1	8.5	7.9	7.2	6.5	5.7	4.6	3.0	.....	.....	.....	.....	3
11.....	12.2	11.5	11.1	10.5	10.0	9.3	8.7	8.0	7.2	6.2	5.1	3.3	.....	.....	.....	.....	2
12.....	13.3	12.6	12.1	11.5	10.9	10.1	9.4	8.7	7.8	6.8	5.5	3.6	.....	.....	.....	.....	6
13.....	14.4	13.6	13.1	12.5	11.8	10.9	10.1	9.4	8.5	7.4	6.0	3.9	.....	.....	.....	.....	22
14.....	15.5	14.6	14.1	13.4	12.7	11.8	10.9	10.1	9.1	7.9	6.4	4.3	.....	.....	.....	.....	20
15.....	16.6	15.7	15.1	14.4	13.5	12.6	11.7	10.9	9.8	8.5	6.8	4.5	.....	.....	.....	.....	12
16.....	17.7	16.8	16.2	15.4	14.4	13.4	12.5	11.5	10.4	9.1	7.3	4.9	.....	.....	.....	.....	11
17.....	18.8	17.8	17.2	16.3	15.3	14.2	13.2	12.2	11.0	9.5	7.6	5.1	.....	.....	.....	.....	8
18.....	20.0	18.9	18.2	17.3	16.1	15.0	14.0	13.0	11.7	10.1	8.1	5.5	.....	.....	.....	.....	5
19.....	21.1	20.0	19.3	18.3	17.1	15.8	14.7	13.6	12.4	10.7	8.6	5.9	.....	.....	.....	.....	.....
20.....	22.3	21.1	20.4	19.2	17.9	16.6	15.5	14.3	12.9	11.1	8.9	6.2	.....	.....	.....	.....	.....
21.....	23.4	22.2	21.4	20.2	18.7	17.4	16.2	14.9	13.5	11.7	9.4	6.4	.....	.....	.....	.....	1
22.....	24.6	23.3	22.5	21.2	19.6	18.2	17.0	15.6	14.0	12.1	9.8	6.7	.....	.....	.....	.....	90

TABLE 49.—*Taper measurements (diameter inside bark) of red spruce in West Virginia—Continued.*

90-FOOT TREES.

[CURVED.]

Diameter breast high.	Height above ground—Feet.															Basis.	
	1	2	3	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.95		98.8
	Diameter inside bark—Inches.																
<i>Inches.</i>	13.3	12.6	12.1	11.5	10.9	10.1	9.4	8.8	8.1	7.3	6.4	5.1	3.6				<i>Trees.</i>
12.....	13.3	12.6	12.1	11.5	10.9	10.1	9.4	8.8	8.1	7.3	6.4	5.1	3.6				1
13.....	14.4	13.6	13.1	12.5	11.8	11.0	10.3	9.5	8.8	8.0	7.0	5.6	3.9				6
14.....	15.5	14.6	14.1	13.4	12.8	11.8	11.0	10.3	9.6	8.7	7.5	6.1	4.3				6
15.....	16.6	15.7	15.1	14.4	13.7	12.6	11.8	11.0	10.2	9.3	8.1	6.5	4.6				6
16.....	17.7	16.8	16.2	15.4	14.6	13.4	12.6	11.9	11.0	9.9	8.6	7.0	5.0				14
17.....	18.8	17.8	17.2	16.3	15.5	14.2	13.3	12.5	11.7	10.6	9.2	7.5	5.3				9
18.....	20.0	18.9	18.2	17.3	16.4	15.1	14.2	13.3	12.4	11.2	9.8	7.9	5.6				4
19.....	21.1	20.0	19.3	18.3	17.3	16.0	15.0	14.1	13.1	11.9	10.3	8.4	5.9				8
20.....	22.3	21.1	20.4	19.2	18.1	16.7	15.7	14.8	13.7	12.5	10.9	8.8	6.2				10
21.....	23.4	22.2	21.4	20.2	19.1	17.6	16.5	15.5	14.4	13.1	11.4	9.3	6.5				5
22.....	24.6	23.3	22.5	21.2	19.9	18.4	17.4	16.3	15.2	13.7	11.9	9.7	6.8				2
23.....	25.7	24.4	23.6	22.2	20.9	19.3	18.1	17.0	15.9	14.3	12.4	10.1	7.2				3
24.....	26.9	25.5	24.6	23.2	21.7	20.0	18.9	17.8	16.5	15.0	13.0	10.6	7.5				
25.....	28.0	26.6	25.6	24.2	22.6	20.8	19.7	18.6	17.2	15.6	13.5	11.0	7.7				
26.....	29.2	27.7	26.7	25.2	23.5	21.6	20.4	19.2	17.9	16.3	14.1	11.4	8.1				
68																	

100-FOOT TREES.

14.....	15.5	14.6	14.1	13.4	12.7	11.8	11.0	10.3	9.8	9.2	8.3	7.2	5.9	4.2	2.2	
15.....	16.6	15.7	15.1	14.4	13.6	12.6	11.8	11.2	10.5	9.7	8.9	7.8	6.4	4.5	2.4	4
16.....	17.7	16.8	16.2	15.4	14.6	13.4	12.6	11.9	11.2	10.5	9.6	8.3	6.8	4.9	2.6	3
17.....	18.8	17.8	17.2	16.3	15.5	14.3	13.4	12.6	12.0	11.2	10.2	8.8	7.1	5.2	2.8	5
18.....	20.0	18.9	18.2	17.3	16.3	15.1	14.2	13.4	12.7	11.9	10.8	9.4	7.7	5.6	3.1	12
19.....	21.1	20.0	19.3	18.3	17.2	15.9	15.0	14.2	13.5	12.6	11.4	10.0	8.1	5.9	3.3	5
20.....	22.3	21.1	20.4	19.2	18.2	16.8	15.8	15.0	14.3	13.2	12.0	10.5	8.6	6.2	3.4	10
21.....	23.4	22.2	21.4	20.2	19.1	17.7	16.7	15.8	15.0	13.9	12.7	11.1	9.0	6.6	3.7	12
22.....	24.6	23.3	22.5	21.2	20.0	18.5	17.5	16.6	15.7	14.6	13.2	11.6	9.5	7.0	3.9	11
23.....	25.7	24.4	23.6	22.2	21.0	19.4	18.4	17.4	16.4	15.3	13.9	12.1	9.9	7.3	4.1	5
24.....	26.9	25.5	24.6	23.2	21.8	20.3	19.1	18.2	17.2	15.9	14.5	12.6	10.4	7.7	4.4	1
25.....	28.0	26.6	25.6	24.2	22.8	21.0	19.9	18.9	17.8	16.6	15.1	13.2	10.8	8.0	4.6	3
26.....	29.2	27.7	26.7	25.2	23.6	21.9	20.7	19.7	18.6	17.3	15.8	13.8	11.3	8.4	4.9	
27.....	30.4	28.8	27.7	26.2	24.5	22.7	21.4	20.4	19.2	17.9	16.3	14.3	11.8	8.8	5.1	1
28.....	31.5	29.9	28.8	27.2	25.4	23.5	22.2	21.1	19.9	18.5	16.9	14.8	12.3	9.1	5.3	
29.....	32.7	31.0	29.9	28.2	26.3	24.4	23.1	21.9	20.6	19.2	17.4	15.3	12.8	9.5	5.5	
30.....	33.9	32.2	31.0	29.2	27.2	25.2	23.8	22.5	21.3	19.8	18.1	15.9	13.2	9.9	5.8	
31.....	35.1	33.3	32.0	30.1	28.1	26.0	24.6	23.3	22.0	20.5	18.6	16.4	13.6	10.2	6.0	1
32.....	36.3	34.4	33.1	31.1	29.0	26.8	25.3	24.0	22.6	21.1	19.2	16.9	14.1	10.7	6.3	
33.....	37.6	35.5	34.2	32.1	30.0	27.6	26.2	24.8	23.4	21.8	19.8	17.5	14.6	11.1	6.6	1
34.....	38.8	36.6	35.2	33.1	30.9	28.4	27.0	25.5	24.0	22.4	20.4	17.9	15.1	11.5	6.8	
																74

110-FOOT TREES.

16.....	17.7	16.8	16.2	15.4	14.5	13.4	12.6	12.0	11.5	11.0	10.4	9.4	8.0	6.4	4.7	2.7
17.....	18.8	17.8	17.2	16.3	15.4	14.3	13.4	12.8	12.2	11.7	11.0	9.9	8.5	6.8	5.0	2.8
18.....	20.0	18.9	18.2	17.3	16.3	15.1	14.2	13.6	13.1	12.4	11.7	10.5	9.0	7.3	5.3	3.1
19.....	21.1	20.0	19.3	18.3	17.3	15.9	15.0	14.4	13.8	13.2	12.3	11.0	9.5	7.6	5.5	3.3
20.....	22.3	21.1	20.4	19.2	18.2	16.8	15.9	15.2	14.6	13.8	12.9	11.6	10.0	8.0	5.8	3.4
21.....	23.4	22.2	21.4	20.2	19.1	17.7	16.7	16.1	15.4	14.6	13.6	12.2	10.5	8.4	6.2	3.6
22.....	24.6	23.3	22.5	21.2	20.1	18.6	17.6	16.8	16.1	15.3	14.3	12.8	11.0	8.9	6.5	3.8
23.....	25.7	24.4	23.6	22.2	21.1	19.5	18.5	17.6	16.9	16.1	15.0	13.4	11.5	9.3	6.8	4.0
24.....	26.9	25.5	24.6	23.2	21.9	20.4	19.3	18.5	17.7	16.7	15.6	14.0	12.1	9.8	7.2	4.2
25.....	28.0	26.6	25.6	24.2	22.9	21.3	20.2	19.3	18.5	17.5	16.2	14.6	12.6	10.2	7.4	4.4
26.....	29.2	27.7	26.7	25.2	23.9	22.2	21.0	20.1	19.2	18.2	16.9	15.2	13.1	10.6	7.8	4.6
27.....	30.4	28.8	27.7	26.2	24.8	23.1	21.9	20.9	19.9	18.8	17.5	15.8	13.7	11.1	8.1	4.8
28.....	31.5	29.9	28.8	27.2	25.8	24.0	22.8	21.7	20.7	19.6	18.2	16.4	14.2	11.6	8.5	5.0
29.....	32.7	31.0	29.9	28.2	26.7	24.9	23.7	22.6	21.5	20.3	18.8	16.9	14.7	12.0	8.9	5.2
30.....	33.9	32.2	31.0	29.2	27.6	25.9	24.6	23.4	22.2	20.9	19.4	17.6	15.3	12.5	9.2	5.4
31.....	35.1	33.3	32.0	30.1	28.6	26.8	25.4	24.2	23.0	21.7	20.1	18.1	15.7	12.9	9.6	5.6
32.....	36.3	34.4	33.1	31.1	29.6	27.7	26.3	25.0	23.8	22.4	20.7	18.7	16.3	13.4	9.8	5.8
33.....	37.6	35.5	34.2	32.1	30.6	28.7	27.2	25.9	24.6	23.1	21.4	19.3	16.9	13.9	10.2	6.0
34.....	38.8	36.6	35.2	33.1	31.5	29.6	28.1	26.9	25.3	23.8	22.0	20.0	17.5	14.4	10.5	6.1
35.....	40.0	37.7	36.3	34.1	32.4	30.5	29.0	27.7	26.1	24.5	22.6	20.5	18.0	14.8	10.7	6.3
36.....	41.2	38.8	37.4	35.1	33.4	31.4	29.8	28.3	26.9	25.2	23.3	21.2	18.6	15.3	10.9	6.5
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STAND TABLES.

Tables 50 to 53 are all stand tables for the spruce slope type and serve as a rough basis for comparison between the four States within which the red spruce principally occurs. The principal associates are balsam, yellow birch, beech, hemlock, sugar maple, and red maple, with incidental arborvitæ, white pine, and numerous hardwoods. These vary much from one place to another.

TABLE 50.—*Stand of spruce and associates on spruce slope type in Maine—Average stand for 20 acres, culled.*¹

[Data collected by R. S. Hosmer in Squaw Mountain Township in 1902.]

Diameter breast high.	Number of trees per acre.			Other species.
	Spruce.	Other species.	Total.	
<i>Inches.</i>				<i>Per cent.</i>
1.....	67.90	26.55	94.45	28
2.....	63.65	27.40	91.05	30
3.....	47.25	20.40	67.65	30
4.....	31.05	13.00	44.05	30
5.....	20.40	9.25	29.65	31
6.....	16.20	6.95	23.15	30
7.....	12.65	4.35	17.00	26
8.....	9.70	3.85	13.55	28
9.....	5.75	2.40	8.15	29
10.....	5.10	2.35	7.45	32
11.....	2.55	1.95	4.50	43
12.....	3.05	1.20	4.25	28
13.....	2.15	.95	3.10	31
14.....	1.15	1.40	2.55	55
15.....	1.40	.90	2.30	39
16.....	1.35	.65	2.00	32
17.....	.85	.40	1.25	40
18.....	.60	.40	1.00	40
19.....	.70	.40	1.10	36
20.....	.30	.40	.70	57
21.....	.15	.20	.35	57
22.....	.15	.35	.50	70
23.....	.15	.10	.25	40
24.....	.05	.25	.30	83
25.....		.05	.05	100
26.....		.05	.05	100
27.....				
28.....				
29.....		.05	.05	100
30.....		.05	.05	100
31.....				
32.....		.05	.05	100
Total.....	294.25	126.30	420.55	30
Trees 10 inches and over.....	19.70	12.15	31.85	38
Trees 12 inches and over.....	12.05	7.85	19.90	39
	<i>Sq. ft.</i>	<i>Sq. ft.</i>	<i>Sq. ft.</i>	<i>Per cent.</i>
Total basal area.....	41.5	23.6	65.1	36
Trees 10 inches and over.....	19.5	14.5	34.0	43
Trees 12 inches and over.....	15.0	11.9	26.9	44

¹ Culled 30 years before, removing trees with a total basal area of 4.2 square feet; culled 5 years before, removing trees with a total basal area of 33.3 square feet; culled 1 year before, removing trees with a total basal area of 16.5 square feet.

TABLE 51.—*Stand of spruce and associates on spruce slope type in New Hampshire—
Average stand for 65 acres.*

[Data collected by A. K. Chittenden in Waterville Township in 1903.]

Diameter breast high.	Number of trees per acre.			Other species.
	Spruce.	Other species.	Total.	
<i>Inches.</i>				<i>Per cent.</i>
2.....	22.20	19.96	42.16	47
3.....	15.51	12.01	27.52	44
4.....	14.28	12.08	26.36	46
5.....	12.94	10.59	23.53	45
6.....	11.20	8.21	19.41	42
7.....	10.48	6.76	17.24	39
8.....	10.45	6.83	17.28	40
9.....	11.14	5.13	16.32	32
10.....	11.03	5.39	16.42	33
11.....	10.29	3.57	13.86	26
12.....	10.38	3.08	13.46	23
13.....	9.12	2.64	11.76	22
14.....	9.22	2.44	11.66	21
15.....	7.52	1.91	9.43	20
16.....	7.89	1.62	9.51	17
17.....	5.80	1.21	7.01	17
18.....	5.12	1.11	6.23	13
19.....	3.40	.90	4.30	21
20.....	2.48	.95	3.43	28
21.....	2.34	.84	3.18	26
22.....	1.18	.66	1.84	36
23.....	.68	.31	.99	31
24.....	.45	.28	.73	38
25.....	.29	.18	.47	38
26.....	.11	.23	.34	68
27.....	.15	.12	.27	44
28.....	.09	.04	.13	31
29.....		.05	.05	100
30.....		.05	.05	100
31.....		.02	.02	100
32.....				
33.....		.02	.02	100
34.....		.02	.02	100
35.....		.02	.02	100
Total.....	195.74	109.28	305.02	36
Trees 10 inches and over.....	87.54	27.66	115.20	24
Trees 12 inches and over.....	66.22	18.70	84.92	22
Total basal area.....	<i>Sq. ft.</i> 122.1	<i>Sq. ft.</i> 45.3	<i>Sq. ft.</i> 167.4	<i>Per cent.</i> 27
Trees 10 inches and over.....	104.2	33.7	137.9	24
Trees 12 inches and over.....	91.4	28.4	119.8	24

TABLE 52.—*Stand of spruce and associates on spruce slope type in New York—Average stand for 37 acres.*

[Data collected by R. S. Hosmer in Township 40, Hamilton County, in 1900.]

Diameter breast high.	Number of trees per acre.			Other species.
	Spruce.	Other species.	Total.	
<i>Inches.</i>				<i>Per cent.</i>
5.....	12.35	0.95	13.30	7
6.....	9.35	.46	9.81	5
7.....	7.86	.22	8.08	3
8.....	6.57	.14	6.71	2
9.....	6.24	.22	6.46	3
10.....	5.05	.32	5.37	6
11.....	4.57	.19	4.76	4
12.....	3.81	2.23	6.04	37
13.....	3.41	1.53	4.94	31
14.....	3.35	1.92	5.27	36
15.....	2.22	1.61	3.83	42
16.....	2.03	1.46	3.49	42
17.....	1.65	1.20	2.85	42
18.....	1.19	1.05	2.24	47
19.....	.84	1.03	1.87	55
20.....	.70	.87	1.57	55
21.....	.32	.89	1.21	74
22.....	.19	.59	.78	76
23.....	.08	.70	.78	90
24.....	.08	.54	.62	87
25.....	.03	.38	.41	93
26.....		.41	.41	100
27.....	.05	.21	.26	81
28.....		.16	.16	100
29.....		.22	.22	100
30.....		.05	.05	100
31.....		.03	.03	100
32.....		.03	.03	100
33.....		.03	.03	100
34.....		.03	.03	100
Total.....	71.94	19.67	91.61	21
Trees 10 inches and over.....	29.57	17.68	47.25	37
Trees 12 inches and over.....	19.95	17.17	37.12	46
	<i>Sq. ft.</i>	<i>Sq. ft.</i>	<i>Sq. ft.</i>	<i>Per cent.</i>
Total basal area.....	41.6	31.3	72.9	43
Trees 10 inches and over.....	31.0	30.9	61.9	50
Trees 12 inches and over.....	25.2	30.6	55.8	55

TABLE 53.—*Stand of spruce and associates on spruce slope type in West Virginia—Average stand for 100 acres.*

[Data collected by John Foley in Greenbrier County in 1902.]

Diameter breast high.	Number of trees per acre.			Other species.
	Spruce.	Other species.	Total.	
<i>Inches.</i>				<i>Per cent.</i>
1.....	17.05	11.06	28.11	39
2.....	18.92	12.19	31.11	39
3.....	20.44	10.95	31.39	35
4.....	14.01	8.22	22.23	37
5.....	9.01	6.70	15.71	43
6.....	6.03	4.94	10.97	45
7.....	5.19	3.87	9.06	43
8.....	4.24	3.17	7.41	43
9.....	2.95	2.36	5.31	44
10.....	2.79	2.49	5.28	47
11.....	1.93	1.51	3.44	44
12.....	1.71	1.59	3.30	48
13.....	1.56	1.35	2.91	46
14.....	1.55	1.36	2.91	47
15.....	1.35	1.27	2.62	48
16.....	1.20	.95	2.15	44
17.....	1.10	.99	2.09	47
18.....	1.17	.83	2.00	41
19.....	.84	.84	1.68	50
20.....	.88	.81	1.69	48
21.....	.85	.76	1.61	47
22.....	.73	.56	1.29	47
23.....	.44	.65	1.09	60
24.....	.56	.65	1.21	54
25.....	.55	.39	.94	41
26.....	.33	.37	.70	53
27.....	.38	.36	.74	49
28.....	.27	.41	.68	60
29.....	.11	.28	.39	72
30.....	.23	.23	.46	50
31.....	.12	.24	.36	67
32.....	.04	.28	.32	87
33.....	.10	.09	.19	47
34.....	.03	.27	.30	90
35.....	.03	.15	.18	83
36.....	.02	.08	.10	80
37.....		.03	.03	100
38.....		.08	.08	100
39.....		.01	.01	100
40.....		.01	.01	100
41.....		.01	.01	100
42.....		.02	.02	100
Total stand.....	118.71	83.38	202.09	41
Trees 10 inches and over.....	20.87	19.92	40.79	49
Trees 12 inches and over.....	16.15	15.92	32.07	50
Total basal area.....	<i>Sq. ft.</i> 43.6	<i>Sq. ft.</i> 45.7	<i>Sq. ft.</i> 89.3	<i>Per cent.</i> 51
Trees 10 inches and over.....	34.3	39.1	73.4	53
Trees 12 inches and over.....	31.5	36.7	68.2	54

SAMPLE PLOTS.

Table 54 gives in summary form the sample plot data used as a basis for the "second-growth" spruce yield table (Table 17).

TABLE 54.—*Summary of spruce sample plot data used as a basis for the second-growth or "old-field" yield table (Table 17).*

Plot No.	Age.	Qual-ity. ¹	Trees per acre. ²				Basal area. ²				Average diameter breast high. ³			Average height dominant and intermediate.	Yield (from dominant and intermediate trees only). ⁴			Area.	Location.
			All green.	Green 6 inches and over.	Dominant and intermediate.	Dead.	All green.	Green 6 inches and over.	Dominant and intermediate.	Dominant and intermediate.	All green.	Green 6 inches and over.	Dominant and intermediate.		Ed.fed.	Cu.ft.	Cords.		
1	Yrs. 75	II	810	683	455	597	71	Sq. ft. 283.50	Sq. ft. 265.58	Sq. ft. 208.82	Sq. ft. 243.53	Ins. 8.4	Ins. 9.2	Ins. 8.6	60	29,346	6,616	67.5	Lincoln (Brown Lot), Me.
2	70	II	650	590	400	580	30	260.60	252.70	203.90	250.70	8.6	8.9	8.9	56	31,630	6,619	67.5	E. Winn (Crocker Lot), Me.
3	66	II	728	625	380	558	255	246.53	234.95	171.85	216.45	7.9	8.3	8.4	54	25,261	5,562	56.2	E. Millinocket (Freeman Powers Lot), Me.
4	68	III	763	503	390	550	297	200.47	183.43	158.90	188.17	7.1	8.2	7.9	53	18,603	4,583	43.3	Bethel (Porter Farwell Lot), Me.
5	71	III	1,111	698	444	751	493	259.20	210.98	153.78	213.51	6.5	7.4	7.2	52	19,387	5,107	48.2	Magalloway Settlement (Brown Farm), Me.
6	72	III	976	714	442	672	460	256.34	225.22	162.32	211.00	6.9	7.6	7.6	51	20,810	5,050	49.5	Do.
7	68	II	830	665	405	620	570	261.25	230.80	173.05	224.95	7.6	8.9	8.2	59	26,710	5,983	59.3	Do.
8	71	III	1,005	660	440	660	780	237.80	194.65	146.80	189.35	6.6	7.4	7.3	53	17,295	4,668	43.8	Do.
9	67	I	1,010	665	440	660	785	241.10	197.95	146.80	189.35	6.6	7.4	7.3	53	17,295	4,668	43.8	Do.
10	67	I	1,050	680	420	660	820	285.30	236.90	145.20	208.30	7.1	7.6	7.3	55	24,730	6,586	61.3	Magalloway Settlement (Kimball Pasture), Me.
11	68	I	825	675	505	660	320	279.15	260.60	213.35	254.70	7.9	8.4	8.4	59	31,020	6,742	67.7	Dummer (Pontook Dam Lot), N. H.
12	61	III	1,116	656	480	776	436	230.20	176.76	139.64	188.48	6.2	7.0	6.7	48	12,224	4,045	34.6	West Milan, N. H.
13	61	I	627	557	383	498	90	253.67	244.37	195.30	227.67	8.6	9.0	9.2	58	29,217	6,054	61.2	Dummer (Pontook Dam Lot), N. H.
14	68	II	540	520	333	460	60	230.34	227.87	169.67	213.34	8.8	9.0	9.2	52	25,030	5,240	52.9	West Milan (Nay Lot), N. H.
15	23	I	3,017	33	3,017	3,017	17	129.00	6.67	129.00	129.00	2.8	6.0	2.8	22	.....	.....	.....	Stark, N. H.
16	33	II	1,820	200	1,540	1,820	940	181.00	40.00	169.00	181.00	4.3	6.0	4.3	27	.....	.....	.....	Stark (Polter Lot), N. H.

16	52	II	{ 820 850 525 }	515 280	465 555 525	201.50 164.90 107.20	146.30	6.7	7.7	8.4	7.6	51	14,150	3,432	32.8	.2	{ Stark (Widows' Lot), N. H.
17	51	I	{ 526 549 549 }	400 293	480 410	780 270.60 187.90	243.60 191.00 130.87	7.6 8.5 { 8.6 8.0 8.7 }	9.4 9.0 { 9.4 8.7 8.8 }	9.4 8.7	56	27,000	5,636	57.2	.05	Do.	
18	46	I	{ 546 549 447 }	293	410	{ 117 140 102.97 }	178.73 130.87 152.77	{ 8.1 8.0 8.7 }	8.6 8.7	9.4	54	20,154	4,272	42.3	.3	{ Stark (Nash Stream Lot), N. H.	
19	73	II	{ 740 760 620 }	440	593	800 223.20 207.73	168.00 199.40 168.00	{ 6.1 6.1 6.1 }	7.2 7.8 8.4	8.4	61	22,766	5,565	54.1	.15	Groton (Hall Lot), Vt.	
20	54	II	{ 1,260 1,267 667 }	667	540	887 907 252.13	213.33 233.33 161.87	{ 6.0 6.0 6.1 }	7.2 7.2 { 7.2 7.2 7.2 }	6.6	48	15,100	4,690	39.9	.15	Do.	
21	62	III	{ 1,527 1,527 640 }	540	767	1,067 268.33 182.87	195.93 159.87 159.87	{ 5.7 6.0 6.0 }	7.2 7.2 7.2	7.4	68	14,107	4,268	37.5	.15	Glenciff (Sanitarium Lot), N. H.	
22	50	III	2,310	620	810	2,720	302.90	147.50	6.6	6.3	5.7	46	7,770	4,312	28.4	.1	Glenciff (Pike Tract), N. H.
23	62	I	1,270	940	600	990	420	304.30	7.2	7.8	7.1	50	20,750	6,256	57.1	.1	Do.
24	71	III	1,296	776	644	1,004	960	266.16	7.0	7.1	6.6	47	14,232	4,806	40.8	.25	Pike (Club House Tract), N. H.
25	61	III	1,265	745	530	905	555	264.95	7.1	7.5	6.8	46	15,335	4,692	41.2	.2	Do.
26	53	II	1,408	668	548	924	672	254.88	6.9	7.1	6.4	47	11,316	4,344	35.3	.25	Grantham (Green Lot), N. H.
27	67	II	792	652	368	592	704	231.88	7.3	8.6	7.8	62	24,256	5,765	58.1	.25	Grantham (Draper Lot), N. H.
28	75	III	788	584	404	584	368	204.92	7.5	8.0	7.4	46	16,220	3,875	36.7	.25	Do.
29	64	I	835	720	435	675	365	268.15	8.1	8.8	8.4	57	27,975	6,328	63.2	.2	Do.
30	30	77	560	516	336	448	324	242.36	9.2	10.3	9.5	62	30,612	6,371	63.4	.25	Do.
31	57	II	896	610	453	656	180	224.66	6.8	7.7	7.5	47	18,351	4,521	43.2	.3	Grantham (Green Lot), N. H.
32	62	III	1,140	608	492	820	1,216	224.20	7.1	7.3	6.6	51	12,968	4,456	35.7	.25	Grantham (Corbin Park), N. H.
33	80	III	1,234	773	617	904	1,310	286.74	7.4	7.6	7.0	51	19,873	5,551	50.0	.3	Do.
34	51	II	1,320	640	540	880	1,620	255.20	6.5	7.4	6.6	48	13,660	4,488	37.6	.05	Plainfield (Corbin Park), N. H.
35	71	II	895	690	460	680	770	251.10	7.2	7.8	7.7	54	23,195	5,474	53.2	.2	Do.
36	63	I	725	585	370	530	350	253.70	8.0	8.6	8.9	54	26,850	4,704	58.0	.2	Corbin (?) (Corbin Park), N. H.
37	69	II	1,216	872	688	1,064	1,520	275.60	6.4	7.0	7.2	53	18,176	6,087	51.8	.125	Do.
38	66	II	763	690	413	613	1,223	276.36	8.2	8.5	9.4	54	29,283	6,281	63.2	.3	Do.
39	63	II	1,290	810	545	925	1,000	297.65	6.5	7.4	7.8	56	22,850	6,413	58.8	.2	Do.
40	50	I	1,190	700	640	940	325	261.75	6.4	7.1	6.8	53	16,400	5,339	45.7	.2	Bridgewater (Macawes Club Lot), Vt.
41	69	II	803	682	425	613	443	257.43	7.7	8.1	8.2	53	24,908	5,592	55.8	.4	Bridgewater (Furman Lot), Vt.
42	58	I	1,272	856	576	860	856	305.92	6.6	7.4	7.3	51	21,688	5,851	54.9	.25	Do.
43	58	I	886	695	515	700	535	256.55	7.3	7.8	7.8	52	22,640	5,509	53.1	.2	Do.
44	50	III	1,650	590	530	1,000	1,040	252.10	5.3	6.7	6.0	47	7,690	4,061	27.9	.1	Springfield (Baker & Bailey Lot), N. H.

¹ The site quality was first determined separately on the basis of total basal area, of average breast-high diameter, and of volume in board feet, in cubic feet, and in cords and the plot finally assigned to that quality with which it was most commonly identified.

² The plots which have the double figures have their "suppressed and dead" trees inadvertently tallied together. The smaller of the two figures assumes that all the trees so tallied were dead; the larger figure that all were suppressed.

³ The top diameter limits for these measurements were the same as those indicated in footnotes 3, 4, and 5, Table 17, page —. The yield of plots less than 40 years old was not calculated.

The data on plots 1 to 51 were collected in 1910 by E. D. Fletcher and the author. The remaining 8 plots are permanent sample plots previously established by the Forest Service and remeasured in 1911 by W. D. Sterrett in collaboration with the author.

TABLE 54.—Summary of spruce sample plot data used as a basis for the second-growth or "old-field" yield table (Table 17).—Continued.

Plot No.	Age.	Qual- ity. ¹	Trees per acre. ²				Basal area. ²				Average diameter breast high. ²				Average height dom- inant and in- ter- me- diate.	Yield (from domi- nant and interme- diate trees only). ³	Area.	Location.	
			Green 6 inches and over.	Dom- inant and inter- me- diate.	Dead.	All green.	Green 6 inches and over.	Dom- inant and in- terme- diate.	All green.	Green 6 inches and over.	Dom- inant and in- terme- diate.	Ins. 7.3	Ins. 7.6	Ins. 7.0					
			960	627	507	747	400	219.73	Sq. ft. 182.73	Sq. ft. 158.27	Sq. ft. 200.00	8.8	9.3	9.2	51	15,534	4,873	39.9	Groton (Hood lot), N. H.
45	57	II	553	473	380	480	60	232.20	228.47	200.00	223.00	7.9	9.4	9.2	54	27,340	5,763	37.8	Woodstock, Vt.
46	67	I	810	670	427	610	253	273.03	278.03	199.43	219.40	8.0	9.3	8.5	61	31,270	6,931	49.4	Do.
47	64	I	785	563	423	536	333	232.37	218.13	188.17	210.57	8.0	9.0	8.5	60	26,687	5,777	58.2	Reading, Vt.
48	69	II	673	493	450	625	160	245.65	229.45	177.15	220.00	7.6	8.5	8.0	57	24,725	5,716	56.8	Do.
49	65	I	725	610	475	575	190	268.65	235.70	223.25	247.60	8.2	8.9	8.9	60	31,300	6,691	57.7	Do.
50	65	I	740	680	475	600	500	252.90	244.50	193.60	227.20	7.9	8.1	8.3	56	25,815	5,782	58.0	Do.
P.S.P. 1	95	II	486	392	382	418	68	209.00	194.84	196.12	201.86	8.9	9.7	9.4	57	24,740	5,836	52.0	Do.
P.S.P. 2	65	II	762	610	590	606	102	243.03	224.72	178.38	236.10	7.6	8.2	8.2	54	24,510	5,823	56.2	Do.
P.S.P. 3	65	III	574	452	452	520	62	187.90	174.72	173.78	183.16	7.7	8.4	8.0	54	20,242	4,567	44.9	Do.
P.S.P. 4	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 5	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 6	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 7	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 8	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 9	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 10	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 11	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 12	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 13	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 14	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 15	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 16	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 17	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 18	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 19	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 20	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 21	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 22	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 23	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 24	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 25	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 26	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 27	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 28	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 29	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 30	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 31	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 32	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 33	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 34	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 35	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 36	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 37	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 38	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 39	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 40	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 41	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 42	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 43	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 44	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 45	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 46	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 47	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 48	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 49	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 50	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 51	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 52	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 53	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 54	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 55	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 56	65	III	414	322	306	358	14	155.36	147.28	143.18	151.34	8.3	9.2	8.8	56	18,026	3,922	38.8	Do.
P.S.P. 57	65	III	414	322	306	358	14												

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IMPORTANT RANGE PLANTS: THEIR LIFE HISTORY AND FORAGE VALUE.

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OBJECT OF THE STUDY.

Although practically all types of grazing lands support a variety of plant species, only a certain proportion of the grasses and of the other plants are important from a grazing standpoint. Some species, owing to their wide distribution and abundance, as well as to the relish with which they are cropped, are valuable forage plants; others because of certain chemical contents either during the entire season or at some period of it are poisonous, and therefore seriously objectionable on the range; while still others, either through some peculiar physical structure or because they contain a superabundance

of tannic acid, which renders them unpalatable are of little or no value for forage.¹

In order to gain an intimate knowledge of the habits, requirements, and life history of the more important species, a study was initiated in 1907 by the Forest Service, in cooperation with the Bureau of Plant Industry, upon the Wallowa National Forest in northeastern Oregon. Data on the relative palatability of the different forage plants were gathered by following bands of sheep and observing their choice of feed as they grazed. Afterwards the relative value of the individual range plants was determined by studying (1) their abundance, distribution, time of flower-stalk production, aggressiveness, reproduction (both vegetatively and by seed), and seed habits; and (2) their palatability and nutritiousness at various times during the grazing season and their ability to withstand trampling. The plan of study and the methods used are fully described at the end of the bulletin.

While the results of the study are largely based upon observations in the high mountains in Oregon between elevations of 5,500 and 8,000 feet, they should nevertheless be helpful to stockmen throughout the West in revegetating the range, since many of the species described are widely distributed, and the genera represented are among those of first importance on most of the natural range lands of the West.

A photograph of each important species in natural size accompanies its description, but where the general characters of two or more species of the same genus are similar, a single photograph is used. With the exception of Plate XXXVIII all specimens selected for photographic purposes were either in flower or fruit, or both, and care was taken to show the general character of the root system, habit of growth, and external structure. Not only will these photographs make possible, in practically every instance, the recognition of the same species when met with in the field, but also other species of the same genus will be recognized as congeneric, although the specific name may not be known to the observer.

CHARACTER OF THE RANGE AND FORAGE STUDIED.

Between the lower and higher grazing lands of the mountains of northeastern Oregon is a difference in elevation of about 7,000 feet. Along with this wide altitudinal variation go widely different growth conditions. Thus, according to the character of the vegetation, the lands studied may be classified into four zones.²

¹ The results of natural revegetation studies based upon observation of the plants described in this bulletin are presented by the writer in U. S. Dept. Agr. Bul. 34, "Range Improvement by Deferred and Rotation Grazing," 1913, and in the Journal of Agricultural Research, Vol. III, No. 2, "Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation," 1914.

² Merriam, C. Hart, "Life Zones and Crop Zones of the United States," U. S. Dept. of Agriculture, Biological Survey Bul. No. 10, 1898.

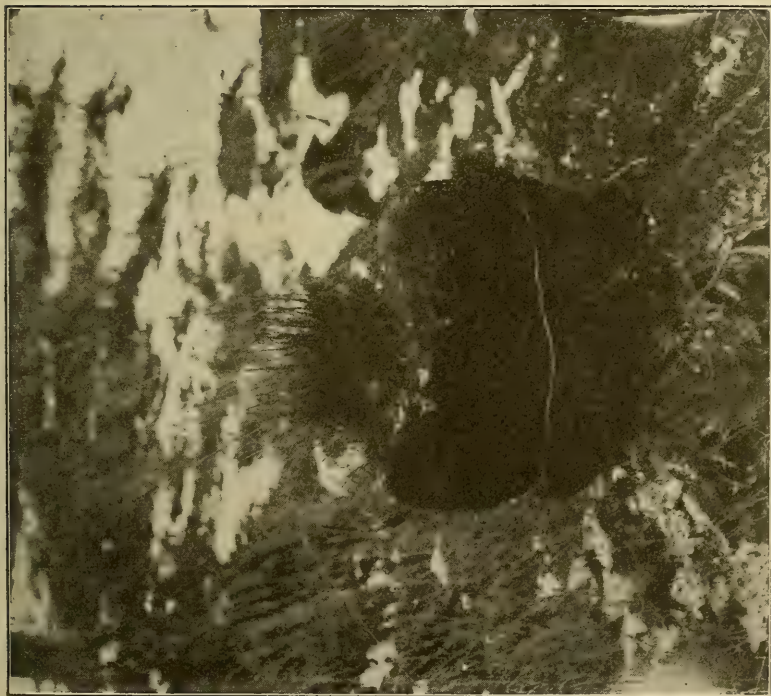


FIG. 1.—Wire-basket method of drying out the soil surrounding the roots. Portability is the chief advantage of this method.

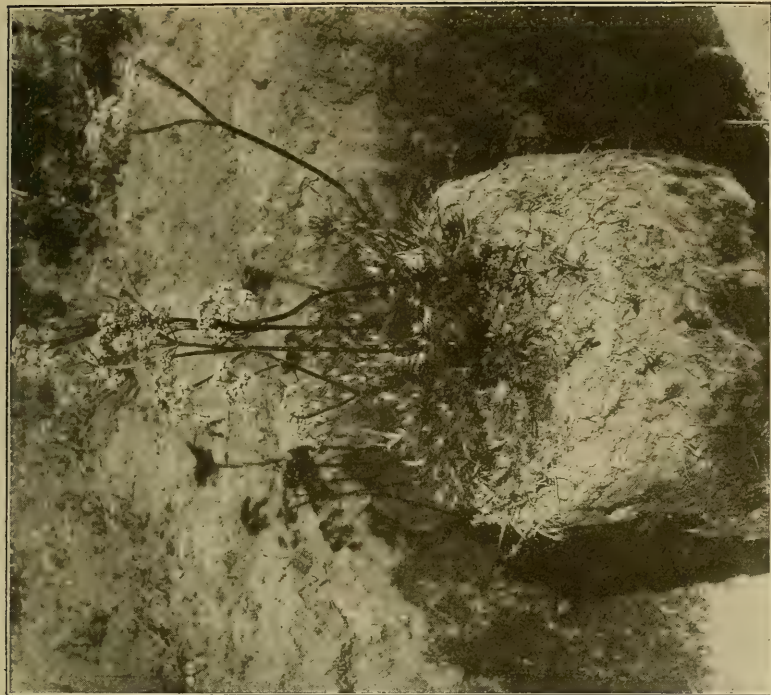
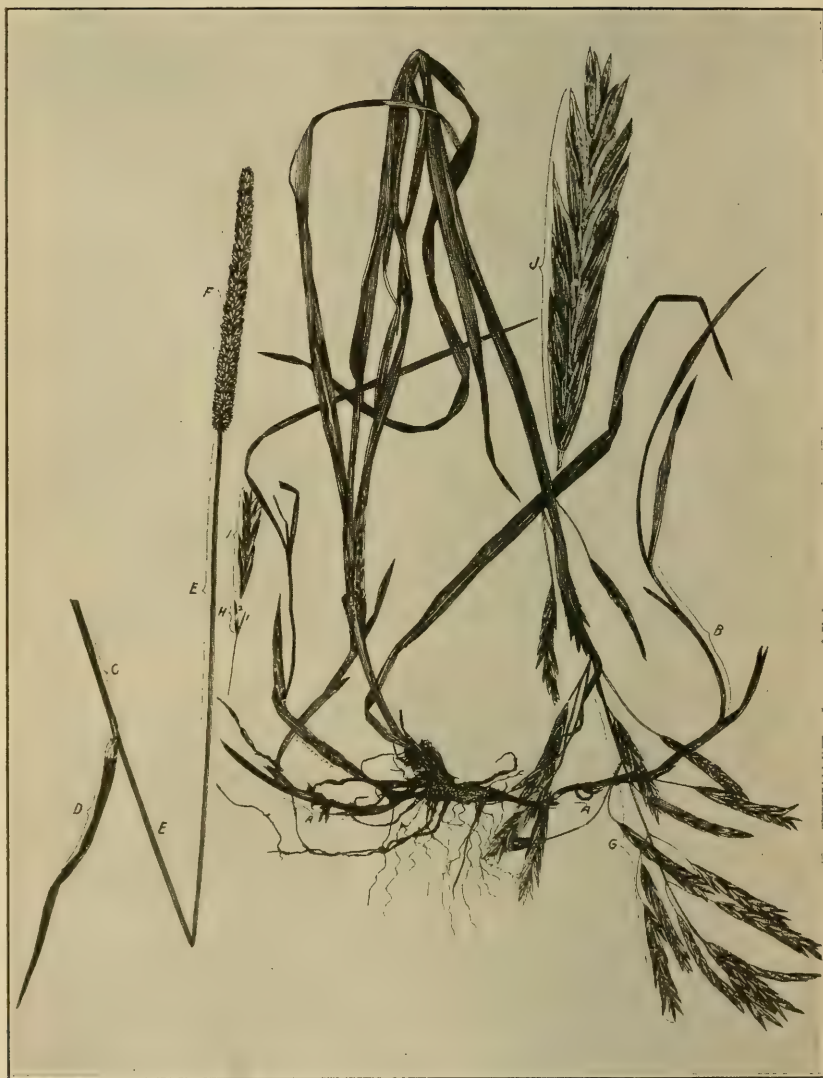


FIG. 2.—The natural-position method. Especially satisfactory in the case of plants with taproots.

METHODS EMPLOYED IN DETERMINING THE WATER REQUIREMENTS. (SEE APPENDIX, P. 61.)



GENERAL MORPHOLOGY OF GRASSES.

F-20

- A. Rhizome or rootstock.
- B. Shoot from rootstock.
- C. Sheath.
- D. Blade.
- E. Culm.
- F. Spikelike panicle of timothy.
- G. Open panicle of brome grass.
- H. Glumes or scales—
 - (1) First glume.
 - (2) Second glume.
- I. Florets.
- J. Natural size of complete brome spikelet. Plants one-third natural size.

1. A Transition zone or yellow-pine association occupying the country between 3,000 and 4,500 feet elevation.
2. A Canadian zone or lodgepole-pine association between 4,500 and 6,800 feet elevation.
3. A Hudsonian zone or white-bark pine association between 6,500 and 8,500 feet elevation.
4. An Arctic-alpine zone or alpine-meadow association from 8,000 feet elevation up.

Owing to the wide difference in the physical conditions in these zones, numerous rather distinct range types occur. The time during which each is grazed varies according to the location.

The Transition zone (yellow-pine association), owing to the open character of the tree stand, supports a rather dense grass cover. Big bunchgrass (*Agropyron spicatum*) occurs in pure stands on the less elevated lands, and pine grass (*Calamagrostis suksdorfii*), blue bunchgrass (*Festuca idahoensis*), little bluegrass (*Poa sandbergii*), and mountain June grass (*Koeleria cristata*), named in the order of their importance, are the most valuable species at somewhat higher elevations. The majority of the important species are herbaceous. This zone is among the first to be grazed in the spring, the lower lands usually supporting stock early in March. By June 1 the forage in the higher adjoining lands is preferred because of its greater succulence.

The Canadian zone (lodgepole-pine association) is more densely forested than the others. Also the forage, instead of being herbaceous, is mainly shrubby or of the "chaparral" type. The most important browse plants in this zone are fire willow (*Salix nuttallii*), black elder (*Sambucus melanocarpa*), high huckleberry (*Vaccinium membranaceum*), and wax currant (*Ribes cereum*). Since the physical conditions in the Canadian zone are intermediate between those of the Transition zone below and the Hudsonian zone above, few plants are wholly confined to this region, and many of the species of the transition zone are encountered here. The grazing period in the Canadian zone comes approximately between May 15 and July 15.

The Hudsonian zone (white-bark pine association) is characterized by scattered small clumps of woodland and a preponderance of grassland. The most important forage species are mountain bunchgrass (*Festuca viridula*), onion grass (*Melica bella*), porcupine grass (*Stipa occidentalis*), wild celery (*Ligusticum oreganum*), and butterweed (*Senecio triangularis*).

While this region is not suited for early grazing, because of the lateness of the growing season, it has as great an area and carries about as many stock as both of the lower zones together. It includes all the high summer sheep lands, except the few crests that are grazed above timber line. The grazing period begins approximately July 15 and continues through August and September.

The Arctic-alpine zone (alpine-meadow association), owing to its small carrying capacity and inaccessibility, has little or no value for grazing, and the character of its vegetation need not be discussed.

On the Wallowa National Forest the vegetation which furnishes the greater part of the forage is distinctly herbaceous. It consists primarily of grasses, sedges, and rushes, with a fair representation of nongrasslike species commonly termed "weeds." While the species are numerous, about 50 furnish virtually all of the range forage.

GENERAL MORPHOLOGY OF GRASSES.

In the discussion of the individual species it will be necessary to refer to specific characters in a general way as a means of distinguishing one species from another. It is essential, therefore, that the reader have a clear conception of what a true grass is. The stems or culms are usually hollow except at the joints (*nodes*). The leaves consist of two parts, the *sheath*, which surrounds the culm usually like a split tube, and the blade. The minute flowers are arranged in spikelets consisting of a shortened axis (the *rachilla*) and from two to many 2-ranked scales, the lower two of which (the *glumes*) are empty, while each of the others (the *lemmas*) bears in its axil a flower inclosed in a 2-nerved scale (the *palea*). Lemma, palea, and flower, together, are termed the *floret*. The spikelets may be sessile (without a footstalk) along a jointed axis (the *rachis*), as in wheat and rye, the whole constituting a spike, or on little stems (*pedicels*) and arranged in panicles, as in mountain bunchgrasses and smooth brome-grass. The head of timothy is a panicle with the branches and pedicels greatly shortened. This is called a spike-like panicle. Sometimes the lemmas or the glumes bear bristlelike appendages termed awns. The "beard" of barley consists of awns.

Plate II has been prepared to illustrate characters which will frequently be alluded to in the following discussion. In this illustration cultivated timothy (*Phleum pratense*) and smooth brome-grass (*Bromus inermis*) are used because they are well known to stockmen and because they represent the morphology of two distinct and important tribes of grasses.

IMPORTANT SPECIES.

GRASSES.

The grass family (*Poaceae*) contains about 3,500 known species. They vary in size from small, mosslike individuals in the extreme Polar regions to treelike growths of a hundred feet or more in the Tropics. As a whole, no family of plants enjoys a wider distribution or grows in a greater variety of soils, and no other family is as important economically. From a grazing viewpoint the grasses are more valuable, all localities considered, than all other plants put together.

The general taxonomic characters of grasses are shown in Plate II.



MOUNTAIN BUNCH GRASS (*FESTUCA VIRIDULA*).

F-30

The specimen shown is in process of fertilization. A, glumes; B, lemma; C, palea; D, the caryopsis or grain.



F-40

PORCUPINE GRASS OR NEEDLE GRASS (*STIPA OCCIDENTALIS*).

The seedling shown is of about the average size attained at the end of the growing season.

KEY TO THE TRIBES AND GENERA.

KEY TO THE TRIBES.

- A. Spikelets upon pedicels in open or spikelike panicles, not in rows.
 - B. Spikelets with but 1 perfect flower (the rachilla prolonged behind the palea as a bristle in *Calamagrostis* and *Cinna*).....Tribe *Agrostideae*.
 - B. Spikelets with 2 or more perfect flowers.
 - C. Glumes usually longer than the first floret; florets with bent awn on the back (excepting *Koeleria*).....Tribe *Aveneae*.
 - C. Glumes much shorter than the first floret, unawned or with a straight awn from the apex.....Tribe *Festuceae*.
- A. Spikelets sessile, in opposite rows along a zigzag jointed rachis forming a spike; leaf blades bearing a pair of earlike appendages at the base.....Tribe *Hordeae*.

KEY TO THE GENERA.

Agrostideae.

- A. Lemmas hardened, having a needlelike point at base and a long, usually twice bent awn at the summit.....Genus *Stipa*.
- A. Lemmas thin and delicate, not needle-pointed at base, awnless or with a minute awn from the back.
 - B. Spikelets in a dense spikelike head; glumes abruptly awn-tipped.
Genus *Phleum*.
 - B. Spikelets in open or narrow panicles; glumes not awn tipped.
 - C. Floret raised on a little stalk; spikelets in a large nodding panicle.
Genus *Cinna*.
 - C. Floret sessile.
 - D. Floret bearing at base copious white hairs sometimes as long as the lemma; rachilla extended behind the palea.....Genus *Calamagrostis*.
 - D. Floret naked or nearly so; rachilla not extended behind the palea, the latter often wanting.....Genus *Agrostis*.

Aveneae.

- A. Lemmas awned.
 - B. Panicles open; lemmas convex, irregularly toothed or 2-lobed, awns arising from below the middle.....Genus *Deschampsia*.
 - B. Panicles narrow or spikelike; lemmas keeled, 2-toothed, the awn arising from above the middle.....Genus *Trisetum*.
- A. Lemmas not awned, panicles spikelike, culms pubescent below panicle.
Genus *Koeleria*.

Festuceae.

- A. Spikelets with upper florets usually sterile, broad and folding about each other, forming a club-shaped mass; glumes shining; lemmas papery, scarious margined.
Genus *Melica*.
- A. Spikelets with upper florets not unlike lower ones in shape, but often reduced in size.
 - B. Spikelets not over 5 mm. ($\frac{1}{8}$ of an inch) long; not awned.
 - C. Lemmas keeled, acute, the nerves not prominent.....Genus *Poa*.
 - C. Lemmas convex, obtuse, the nerves prominent.....Genus *Panicularia*.
 - B. Spikelets 1 cm. ($\frac{2}{5}$ of an inch) or more long, awned or awn-pointed.
 - D. Lemmas 2-toothed, usually awned just below the apex...Genus *Bromus*.
 - D. Lemmas entire, usually awned from the tip.....Genus *Festuca*.



LITTLE NEEDLE GRASS (STIPA MINOR).

F-5G



MOUNTAIN TIMOTHY (PHLEUM ALPINUM).

F-60

Mountain bunch grass (Plate III) forms densely tufted hummocks or bunches. It has coarse, deep, and spreading perennial roots; erect, slender, and smooth culms from 1 to 2 feet high, slightly thickened at the base; a preponderance of rather long inwardly rolled (involute), smooth or somewhat rough basal leaves; and open semi-nodding panicles, composed of rather compressed spikelets, often of a dark purple color, bearing 3 to 6 florets.

As indicated by its usual habitat, mountain bunch grass stands near the head of the list in drought-resistant qualities. Well established plants subjected to the gradual drying process began wilting excessively when the water content was reduced to 9.5 per cent, and did not, as a rule, recover after the per cent of water dropped to 7. Such a low amount of water about the main roots would be very unusual, of course, on the high range, but it shows the possibilities of mountain bunch grass in dry situations.

Observations during 1907, 1908, and 1909 showed that the flower stalks were sent up from July 5 to August 20, July 10 to August 25, and July 3 to August 15 in the respective years. The seed crop for these seasons began to ripen as early as August 5, and by September 5 practically the entire crop had matured. The seeds are disseminated almost immediately upon reaching maturity. Flower-stalk production and seed maturity occur earlier upon coarser, less decomposed soils, where the soil water is readily reduced through evaporation and where the temperature in the substratum is relatively high.

Mountain bunch grass seed has a low viability. The average for all laboratory tests made during the three seasons was 12.2 per cent. Field tests in the natural habitat, with seed from the same source, gave a much higher percentage of germination.

Upon the higher ranges mountain bunch grass is grazed ravenously by all classes of stock. It is most highly relished at the time of flower-stalk production, the entire aerial portion, including the succulent leaves and the flower stalks, often being removed at that time by a single grazing. As the season advances, sheep discriminate between the leaf blades and culms, and when the plant has matured its seeds the latter are rarely cropped. Ripening of the seed crop, however, impairs the plant's palatability and nutritiousness but little. As a rule, the leaf blades are not eaten so closely as earlier in the season, and the fibrous stems or seed stalks remain untouched. But little else of the forage is wasted.

The nutritive value of mountain bunch grass is indicated in Table 1, which also presents an analysis of well cured timothy hay for comparison.

TABLE 1.—*Chemical analysis of mountain bunch grass and timothy hay.*

Material.	Protein (nitro- gen).	Ether extract (fat).	Crude fiber.
Mountain bunch grass:			
Matured plant.....	13.18	2.83	22.20
Growing plant.....	12.24	3.60	21.15
Matured flower stalks.....	4.18	1.30	38.65
Timothy hay.....	6.78	2.87	33.40

It will be seen that there is comparatively little difference in the nutritiousness of mountain bunch grass at the time the flower stalks are being produced and immediately after the seed crop has ripened. The greatest difference in the important constituents is found in the ether extract (fat), which is 27.21 per cent greater in the younger plants. This is partly offset by the fact that there is 7.68 per cent more protein (muscle making nutrients) in the matured plants. The latter also contain 4.96 per cent more crude fiber than the young plants, the most indigestible portion of the forage. In the matured flower stalks the protein (nitrogen) and the ether extract (fat) are very low, while the indigestible (crude fiber) material is very high. This fact explains in part why the flower stalks are not grazed at maturity.

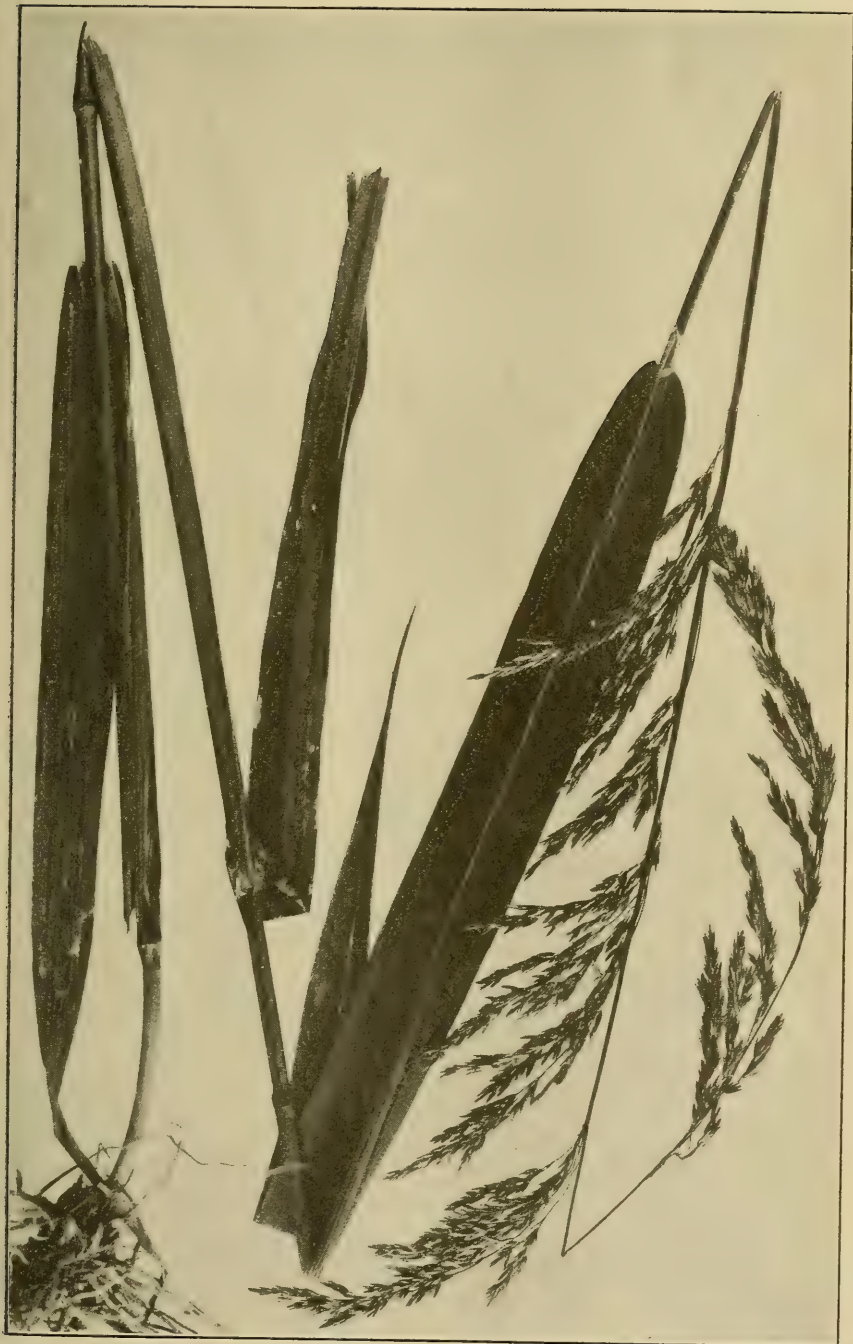
Investigations have shown that well-cured grasses yield as much nutriment as the same grasses when green.¹ There is this distinction, however, that ordinarily the cured forage is not as palatable as the green. But since about half of the basal leaf blades remain green until the end of the grazing season, the palatability and nutritive qualities of mountain bunch grass remain comparatively high after seed maturity.

A plant closely related to the one discussed is blue bunch grass (*F. idahoensis*). Being confined almost entirely to lands of medium elevation, and the herbage having a distinctly bluish color and the awns on the culms and lemmas being about twice the length of those of mountain bunch grass, the two are readily distinguished even though both are distinctly bunch grasses.

The flower stalks of blue bunch grass begin to show about the first week in June in the typical (yellow-pine) habitat and they continue to be produced until about August 1. The seed matures, for the most part, between June 25 and August 15. The seed tested for germination show a viability of from 11 to 21 per cent.

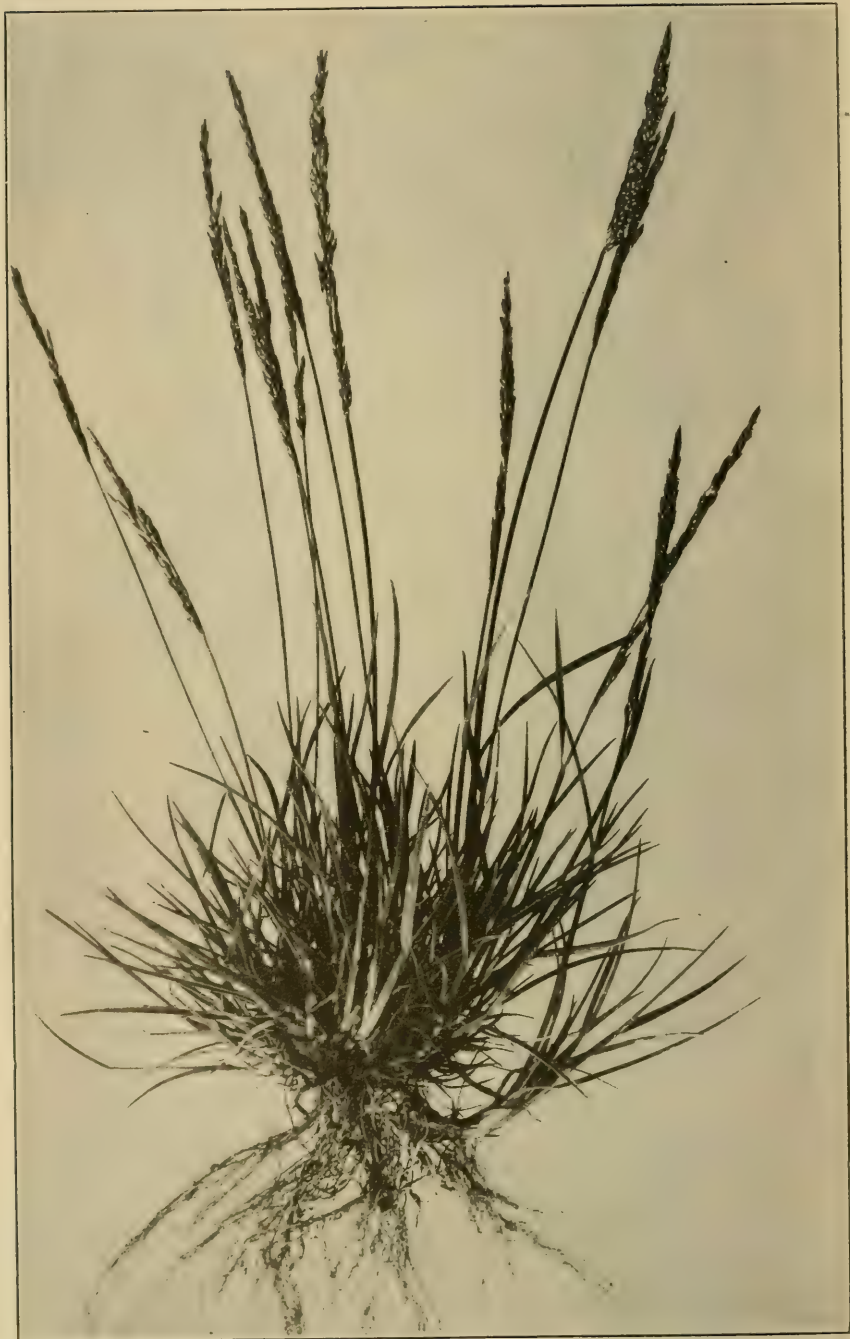
Blue bunch grass furnishes excellent forage for all classes of stock from early spring until the early part of August, when it begins to mature and the leaf blades become somewhat tough and dry. Even at that time it is grazed to a greater or less extent by cattle and horses, but only to a limited extent by sheep. All stock, however, relish

¹ Wolff, E., *Farm Foods*, 1896, English edition, p. 155.



SLENDER REED-GRASS (*CINNA LATIFOLIA*).

F-7G



ALPINE REDTOP (*AGROSTIS ROSSAE*).

F-8a

blue bunch grass in the autumn on account of the new growth resulting from the autumn precipitation. As a whole, it is a palatable and nutritious grass, and, occurring as it does in abundance over well-drained lands of medium elevation, its economic value is high.

PORCUPINE GRASS.

(*Stipa occidentalis*.)

The genus *Stipa* includes a large number of perennial grasses distributed throughout the world. Approximately 30 species are found in the United States, mainly in the West. Many are valuable for grazing purposes, while others are cut for hay.

Porcupine grass (Plate IV) is a perennial bunchgrass with coarse, spreading, and deeply penetrating roots, capable of withstanding an unusual amount of abuse. The leaf blades are mainly basal, somewhat involute (rolled inward), those of the culms shorter than the basal ones, all rather rough and somewhat rigid, the sheaths shorter than the internodes. The panicle is somewhat contracted, about 4 inches long; the spikelets one-flowered; the floret cylindrical, pubescent throughout, with a sharp-pointed bent callus at the base. The empty glumes are subequal, membranaceous, and the lemmas or flowering glumes, which completely inclose the palets, are brownish when mature and bear awns from 1 to 1½ inches long, twice bent and strikingly plumose or densely pubescent to the second joint or knee.

To judge from the tufted habit of growth and the involute leaf blades and their texture, it might be expected that the moisture requirements of porcupine grass would be about the minimum of the species studied. An average of all moisture tests, however, showed that pronounced wilting resulted in the characteristic soil type where the water content varied from 9.5 to 11.5 per cent. In a soil containing 8 per cent of moisture a specimen failed to recover its form and subsequently died. Fearing that some error had crept into the results first obtained, several additional tests were conducted, but the later results agreed with the first.

Porcupine grass inhabits only well-drained soils in open, exposed situations in association with mountain bunchgrass, alpine redtop, short-awned bromegrass, and other species. Its seedlings develop somewhat deeper roots than do the majority of the species, and because of this fact they have thrived during dry periods in certain places where other species able to exist in soil of slightly lower water content have died.

The flower stalks are all produced within a month or less after the first ones appear. They begin to show about July 15. The seeds are, as a rule, well matured by September 10. In 1909, however, they had ripened and were disseminated by August 30. Dissemination follows almost immediately upon maturity.

The seed crop has a fair viability, the average for the three years being 27 per cent. The highest germination, obtained in 1909, was 35 per cent. On the range this species is reproducing so abundantly that it is very probable that a much higher viability results when the seed is allowed to pass through the usual conditions after maturing. The seed, too, has an effective means of getting into the ground through the boring action of the awn, and this may account largely for the plant's rapid invasion of many situations. It is among the most promising species for restocking depleted ranges.

Although not to be compared with mountain bunchgrass in palatability, porcupine grass is a good forage plant. It begins growth early in the season and continues growing until late in the summer, the leaf blades remaining green until September 1. Although their texture is somewhat harsh and their edges slightly scabrous, the plant is grazed with considerable relish by sheep, cattle, and horses, though considered most desirable for sheep. Both cattle and horses eat the flower stalks, even when the seeds are approaching maturity, and the long, rather bristlelike awns are likely to make sore mouths or even to cause serious trouble in the throat, sometimes resulting in what is termed "temporary lump jaw." Other grasses, however, may be more directly responsible for these bad effects. Sheep do not consume the flower or seed stalks, but graze the leaf blades closely.

A species closely allied to porcupine grass is little needle grass (*S. minor*). It is very similar in general characters, ecological requirements, and distribution, and for that reason will not be discussed in detail here. While as widely distributed as *S. occidentalis*, it is not nearly so abundant. The plant is taller and may be distinguished at a glance by observing the awns, which are less than half the length of those of *S. occidentalis*, and which, instead of being plumose, are very slightly pubescent or merely roughened. Because of its sparse growth, the plant is not especially valuable for grazing, though eaten with relish by most classes of stock. (See Plate V.)

MOUNTAIN TIMOTHY.

(*Phleum alpinum*.)

The genus *Phleum* contains about 10 annual and perennial species, most of which are confined to the Temperate and Arctic regions. Among them is the cultivated timothy, generally conceded to be the most valuable forage and hay plant in the United States.

Mountain timothy is occasionally mistaken for the cultivated timothy. While the two plants have somewhat the same general appearance (compare Plates II and VI), the cultivated species, *P. pratense*, usually grows from 2 to 4 feet high, while mountain timothy as a rule attains less than half that height; also the spike of the latter,



F-90

VIEW SHOWING HOW CLOSELY SHEEP GRAZE PINE GRASS IN THE SPRING OF THE YEAR.

The fibrous woody roots and the fact that it forms a turf renders it almost proof against trampling and close grazing. Pine grass is one of the hardest and most prolific grazing plants in the Wallowa Mountains.



F-109

PINE GRASS (*CALAMAGROSTIS SUKSDORFII*).

On the right is shown a pine-grass seedling of 2 months' growth.

about 1 inch long, instead of being cylindrical and having short awns on the glumes like the cultivated species, is ellipsoid or ovate-oblong, the awns about the length of the glumes.

Like the cultivated species, mountain timothy is a perennial plant and has the sheaths of the upper portion of the leafy culms loose as compared with the lower ones. The spikelike panicle is usually purple in color, and the glumes of the spikelets are slightly fringed on the back.

Mountain timothy is confined to alpine and subalpine regions. In the region studied it is closely restricted to the Hudsonian zone. It is a plant of turfy habit, growing in moist meadows and swales, around springs, and along banks of streams. Often the stands are dense and pure. In some places, however, the keenest competition exists between the mountain timothy and certain sedges and rushes, the result being that one species predominates here and another there. Since it grows characteristically in boggy or nearly saturated soils, mountain timothy wilts beyond recovery even though there may be a rather high percentage of moisture in the substratum. The five specimens tested for drought resistance persisted only until the water content was decreased to an average of 14 per cent.

The flower stalks are produced later than those of vegetation in drier situations, since the moister soils are slower in warming up in the spring. Usually the stalks begin to appear about July 15, and are all produced by the end of the first week in August. Mature seeds can generally be found after August 15, and continue to ripen until about the middle of September.

The fertility of the seed crop is considerably above the average for a typical subalpine herbaceous plant. The average per cent for all tests was 69.5, the maximum germination of 76 being obtained in 1909 and the minimum of 58.2 in 1907.

When compared with the average marsh or bog species, mountain timothy ranks high as a forage plant. Early in the summer it is considered by stockmen to be a bit too succulent or "washy," but since sheep naturally avoid its habitat, which is invariably moist at that season, there is little demand for it then. As the season advances, however, the soil becomes drier, and the latter part of the summer this grass is grazed with relish. Mountain timothy remains green and tender unusually late in the fall, and, compared with other species grazed at that time of the year, it is eaten with unusual relish.

SLENDER REED-GRASS.

(*Cinna latifolia*.)

The genus *Cinna* is represented by but three species in the United States. Of these, slender reed-grass (*Cinna latifolia*) is the most important in the localities studied.

Slender reed-grass is a rank growing perennial from 1½ to 4 feet tall. The culms, which are usually very brittle, are bent like a knee at the lower joints. Like the sheaths, the leaf blades are rough, and are especially broad and very flat (Plate VII). The panicle is long, often exceeding 8 inches, open, and usually drooping.

The favorite habitat of slender reed-grass is in sparsely vegetated forests which admit enough light for the undergrowth to succeed. It is closely restricted to shaded situations with well-watered soils.

The inherent tendency toward shade is shown by the unusually wide and flat leaf blades as well as the absence of basal leaves, while the high water requirements are shown, among other things, by the meager development of the root system, the absence of special contrivances to retard transpiration, and the restriction of the species to wet soils. Growing in situations very similar to mountain timothy, it has virtually the same water requirements. Failure to recover from wilting took place in the mucky soil in which this species grows when the moisture content in the case of one specimen was 13.5 per cent and in another 16 per cent.

The flower stalks were produced from July 5 to August 5, July 10 to August 15, and from July 5 to August 10 in 1907, 1908, and 1909, respectively. Compared with the earliest appearance of the flower stalks, the seed reached maturity at a relatively late date, the earliest being about the last week in August. The crop matured evenly, however, with approximately 15 days intervening between the time the earliest seed matured and the major portion ripened.

The length of time required for a seed crop to ripen in nearly all cases seems to influence the vitality of the resulting crop. An even and comparatively short maturing period usually indicates, for a given locality, seed of higher vitality than that which ripens at wholly different dates. The average germination of the seed crop of slender reed-grass for the three seasons was 86.8, and the minimum yearly average, 79 per cent, obtained in 1907.

Since slender reed-grass does not enjoy an especially wide zonal distribution, and is closely restricted to moist situations, it supplies but limited forage. So far as palatability is concerned, however, it ranks high, and since it remains green and tender throughout nearly the entire summer grazing season, the herbage is closely consumed. Owing to the moist condition of its habitat in the early part of the season, the plant is seldom grazed by sheep until August.

ALPINE REDTOP.

(*Agrostis rossae*.)

The genus *Agrostis* is composed of about 100 species, most of which are found in the North Temperate Zone.¹ As indicated by its com-

¹ Hackel, Edward, "The True Grasses," p. 111, 1890.



MARSH PINE GRASS (*CALAMAGROSTIS CANADENSIS*).

A portion of the characteristic creeping rootstocks is shown.

F-110



mon name, alpine redtop is typically a plant of the high grazing lands. On the Wallowa National Forest it is not found below about 6,500 feet. It grows well up to and even a little beyond timber line, having approximately the same distribution as mountain bunchgrass, with which it is commonly associated.

This species, like a great many typical upland plants, is short, rarely exceeding 8 inches in height (Plate VIII). Unlike cultivated redtop, it is distinctly tufted instead of stoloniferous, and has a large number of narrow basal leaves from one-third to one-half the length of the culms. The panicle is rather contracted, about 2 inches long, and the spikelets are purple-green merging into red, one-flowered, with awnless glumes.

Alpine redtop seems best adapted to a well disintegrated basaltic soil relatively rich in humus, characteristic of glades and open plateaus. It wilts beyond recovery in soils of this type having a water content of from 8.5 to as low as 7 per cent. Good stands have often been seen in rather moist habitats, but, as a rule, it succeeds best and is more commonly met with in well-drained soils. Being a bunchgrass, it never completely covers the ground, but in certain localities it is sometimes the main species.

The average time during which the flower stalks were sent forth in 1907, 1908, and 1909 was four weeks. In 1907 they first showed on July 5 and continued to be sent forth until August 15. The seed crop was fairly well ripened at the end of the first week in September.

The germination power of the seed in 1907 was 29 per cent; in 1908, 38 per cent; and in 1909, 41 per cent. For an upland perennial grass these figures are considerably above the average, and in favorable situations the reproduction was good.

While not eaten with the same relish as are a number of its close relatives, alpine redtop is grazed by sheep to a considerable extent, particularly in the fore part of the season. After about August 15, when all the flower stalks have been sent up, the leaf blades become rather tough and unpalatable, and other plants are then preferred. The shortness of its leaf blades, its scattered growth, and the comparatively short period during which it is eaten with relish affect its importance as a forage plant.

PINE GRASS.

(*Calamagrostis suksdorfii*.)

The genus *Calamagrostis*, to which pine grass belongs, contains about 130 species widely distributed throughout temperate and mountain regions. Thirty-eight species, mostly native, occur in North America, mainly in the West. Only three occur in the Southern States, and six of those States are without a single species.

Botanically *Calamagrostis* is closely related to *Agrostis*, the genus to which redtop belongs, but may be distinguished from it by the long, soft, fine hairs on the callus or hardened base of the floret and by the prolongation of the axis of the spikelet behind the palea.

Pine grass makes its most luxuriant growth in the Transition zone, where it grows mainly under the relatively open forest of western yellow pine (*Pinus ponderosa*). It is also found in the Canadian zone, where it often ranks first in abundance and importance among the grass species. In the Hudsonian zone it is found only in the warmer situations of the lower altitudes. (See Plate IX.)

Pine grass (Plate X) may be recognized by its perennial character and its abundant, well-developed, creeping rootstocks which produce a continuous, closely matted sod or turf. The culms, somewhat bunched, grow from 1 to 3 feet tall, and usually bear three short, smooth leaves; the rather numerous lower or basal leaves are somewhat involute, flexible, and smooth. The panicle, pale green until the plant is mature, is contracted and densely flowered, the spikelet bearing but one floret. One pronounced character by which the species may be recognized at a glance is the ring of stiff hairs at the junction of the sheath and blade.

The fibrous, widely spreading and deep root system, make it possible for pine grass to grow in exposed situations where the soil is relatively dry during most of the growing season. (Tests for drought resistance show that this species usually fails to regain its form after wilting notably in a soil containing an average water content of 8.5 per cent. In the case of two specimens turgor was regained in a soil which contained but 5.5 per cent of moisture.)

Owing to the warm and relatively dry situations generally inhabited by pine grass, the flower stalks begin to appear about July 1. The number is comparatively small, and production continues until September 1. On the higher areas flower-stalk production is invariably sparse, with the period of production extending from July 20 to the end of the season. The seed begins to ripen on the lower ranges in late July, and the period of maturity extends until the middle of September. On the higher ranges the first seed ripens by August 10, and the maturing period lasts until unfavorable weather conditions in September. Seed of the last flower stalks produced seldom ripen.

In fertility, the seed of pine grass ¹ ranks about the highest of the native species studied. The lowest vitality observed occurred in 1907, when an average of 58.2 per cent was obtained. In 1908 and 1909 averages of 76 and 74.5 per cent, respectively, were secured. Seed collected at different times in the Transition zone yielded the highest

¹ The seed used in these tests was collected in the upper Canadian zone in the latter part of August of each season.



SLENDER HAIR-GRASS (*DESCHAMPSIA ELONGATA*).

F-13Q



SPIKED TRISETUM (*TRISETUM SPICATUM*).

F-14Q

results in nearly every case, one germination test, the highest of all, giving 98.5 per cent.

Among stockmen there is much diversity of opinion as to the forage value of pine grass. While it may not be included in the category of choice forage plants, except in the spring when it is young and tender, yet it plays a valuable part on the range. In the spring of the year the leaf blades are eaten with nearly as great relish as any of the native grasses, and judging from the condition of the stock feeding upon it, the species has high nutritive qualities. From early spring to about the middle of July, on the lower ranges, all classes of stock graze it closely and with considerable relish. In the latter part of July, however, the tissues of the leaf blades become fibrous and tough, the plant is not grazed with relish, and is then considered to have a much lower nutritive value. In the fall of the year, after the rains have started, it is again grazed to a limited extent, since the leaf blades are somewhat softened by the precipitation.

BLUEJOINT.

(*Calamagrostis canadensis*.)

Bluejoint or marsh pine grass, because it is less abundant and less important than pine grass, is not so well known to stockmen as the latter. Though its distribution is about the same, it does not inhabit pine forests, but grows in marshes and swales and along moist stream banks. The local name is derived from its resemblance to typical pine grass, to which it is closely related.

The two species may readily be distinguished by the panicle (compare Plates X and XI), which in pine grass is dense or contracted and pale green, while in bluejoint it is very loose and open and tinged with brown or pale purple. The latter does not have the characteristic ring of stiff hairs at the junction of the sheath and blade. The culms of marsh pine grass are erect, from $1\frac{1}{2}$ to 3 feet high; the leaves, smooth, long, wide, and distinctly flat. It has rather shallow, lateral roots. Reproduction by root stocks is prolific, and dense stands are common in favorable situations.

The wide, flat leaves, shallow roots, and the situations in which marsh pine grass grows indicate its inability to withstand drought. The soil in which it occurs is well supplied with moisture, but is not especially rich in organic matter. In some of the tests the plants did not succumb until the water was reduced to nearly 11 per cent. In the case of two tests the specimens recuperated from the wilted condition when the soil contained an average of 14 per cent of moisture.

The flower stalks begin to appear about June 25, and by July 20 are nearly all sent up. Mature seed can usually be found by August

1, and by August 20 the main seed crop has ripened. The seed has a high power of germination. The average for all tests made was 71.5 per cent, with a minimum germination of 59.5 per cent.

Owing to its rank growth bluejoint is better suited to cattle and horses than to sheep, yet the latter eat the leaf blades, though rarely the flower stalks even when young. Because of its restriction to moist situations, it is not very abundant, and consequently furnishes a comparatively small amount of forage.

TUFTED HAIR-GRASS.

(*Deschampsia caespitosa*.)

Tufted hair-grass (*Deschampsia caespitosa*) is a member of the same tribe as cultivated oats. Though from its general appearance this fact would not be recognized, yet botanically they are closely related. Tufted hair-grass is often mistaken for redtop, mainly because of its loose panicle, but morphologically it is very different. Redtop has but one flower in a spikelet, while tufted hair-grass has two perfect flowers.

The genus *Deschampsia* is represented by about 20 species, adapted mainly to the cold and temperate regions. About 6 species are found in the western part of the United States.

Tufted hair-grass is a perennial tufted species with rather deep and spreading fibrous roots. The culms are from 1½ to 3 feet tall, erect, and smooth, or in some specimens slightly rough, the leaves mainly basal and very numerous, flat, and often ascending to half the length of the culms. The spikelets, bearing two perfect flowers, are small and shiny, and the panicle is open, the branches widely spreading. Both the empty and the flowering glumes are shiny in appearance (Plate XII). The latter are notched at the apex and bear a short awn on the back.

This species is rarely found in dry situations, but grows abundantly in moist meadows, canyons, and bottom lands, where it frequently predominates. Concerning its density of stand and rankness of growth F. Lamson-Scribner¹ states that it has a record of producing 10,209 pounds of green and 3,318 pounds of dry hay per acre. The minimum amount of soil water with which it will grow varies between 11.5 and 14.5 per cent. In soils containing less than this amount of moisture the wilted leaf blades failed to regain their turgidity.

The first flower stalks appear about July 20, and their production continues until about August 15. As with most species in moist soils, the flower stalks are not produced as early as in the drier situations. The time required for the development of the seeds is rather prolonged, and well-matured seeds are rarely found until

¹ Economic Grasses, U. S. Dept. of Agr., Div. Agrostr. Bul. 14, p. 32, 1900.



MOUNTAIN JUNE GRASS (*KOELERIA CRISTATA*).

F-15G



ONION GRASS OR MOUNTAIN BLUEGRASS (*MELICA BELLA*).

F-100

September 1. By about the middle of September the crop is usually well ripened, and, for the most part, disseminated.

The germination per cent is about the average for an upland plant, the average for all tests conducted during the three years of study showing 26.4 per cent for the seed crop from the Hudsonian zone, where the revegetation studies were made. Seed collected in the Canadian zone germinated as high as 50 per cent. Some seed companies handle seed of this species grown in Europe, which as a rule has a fair germinative strength. It is sold for about \$22 per 100 pounds.

This species is an important forage plant because it occurs frequently throughout the Hudsonian zone, is often met in the Canadian zone, occurs in sufficiently dense stands to make it an appreciable factor in meadow crops, and is eaten with relish. So far as texture is concerned, it is always desirable for cattle and horses, but is often too rank and coarse to be of the highest value for sheep. Nevertheless, as a rule, sheep graze it closely. Densely vegetated meadows of this species grazed by sheep comparatively early in the summer when the root leaves are tender may have the appearance of a newly-mown lawn of bluegrass, so closely is the forage removed. Up to about August 15 tufted hair-grass is highly relished, but after that date the leaf blades take on a fibrous or somewhat woody texture which greatly lessens their palatability. In the latter part of the grazing season it is not usually grazed closely unless it has been cropped earlier in the season, a condition which results in prolonging the growth of the vegetative parts. The aftermath is eagerly consumed by all classes of stock, and especially by sheep. Observations indicate that this species withstands trampling and close grazing better than any other valuable forage grass in the region studied. This fact is due both to the habit of growth of the plant and to the nature of the situations in which it grows.

SLENDER HAIR-GRASS.

(*Deschampsia elongata*.)

Slender hair-grass, though closely related botanically to tufted hair-grass, differs widely from it in general appearance (Plate XIII). Like tufted hair-grass it is a perennial and grows in tussocks, though the latter seldom attain a diameter exceeding 4 inches, and more often are only one-half that size.

Slender hair-grass bears the appearance of an annual grass in that it is very shallow rooted and sends up a preponderance of slender naked seed stalks. The latter are erect and from 8 to 16 inches tall. At the base a prodigious number of narrow, rather smooth but very short root leaves are produced. The panicle is long, often fully one-third the length of the culm, and usually not widely branched.

In the region studied this species has a wide distribution. It occurs most abundantly and grows most luxuriantly in the Canadian zone, though it is met with in a variety of situations in both the upper and lower contiguous zones. In fact, the tendency of slender hair grass to adjust itself to various sites is a marked characteristic. In the well-aerated, finely disintegrated, basaltic soil of the plateaus in the Hudsonian zone this species does not wilt notably until the water content of the soil falls to between 8.5 and 10.0 per cent—a relatively low figure. On the other hand, simultaneous drought tests conducted in soils rich in organic matter, and where the plant had had access to a high per cent of soil water at all times, resulted in destructive wilting of the plant when the soil-water content was as high as 15 per cent. In moist situations a meager root system is developed, and on dry sites, while the root rarely penetrates deeply into the soil, it spreads over considerable surface.

The flower stalks begin to appear about July 10 in the drier situations, and a week or so later in moist places. By August 1 the majority have put in their appearance. Mature seeds are found as early as August 5, while the bulk of the seed crop is matured by August 25. The tests made for seed vitality were confined to the year 1909, and showed an average of 41.5 per cent. On lower ranges somewhat higher figures were obtained, 56.5 being the maximum.

The grazing value of this plant is relatively low, and in this respect it does not compare favorably with tufted hair grass. Owing to its shallow roots the plant is frequently pulled up. Sheep grazing on this plant, especially early in the season when the soil contains a high per cent of moisture and the roots are readily pulled out, start masticating the leaf blades, but usually expel them when they find that roots and clinging dirt form the dessert to their diet. After a few experiences of this kind they crop it but little. Since the tussock is small, horses often pull up the entire tuft, and after eliminating the greater part of the clinging dirt by shaking it vigorously and rubbing it upon the ground, sometimes devour the plant. After about August 15 the leaves become air dried, and slender hair grass is then disregarded as a forage plant by all classes of stock.

Another species known as black hair-grass (*D. atropurpurea*) occurs in scattered stand in open situations throughout the Hudsonian zone. Being restricted to high elevations (it rarely occurs below 6,500 feet), the flower stalks are not seen until July 15 and they continue to be produced until about August 25. No seed is matured until about September 1 and very little fertile seed is developed even in most favorable seasons. Reproduction takes place vegetatively by means of offshoots arising from root stocks.



LITTLE BLUEGRASS (*POA SANDBERGII*).

F-170



SHORT-AWNED BROMEGRASS (*BROMUS MARGINATUS*).

F-180

The sheath on the basal portion of the culm was accidentally removed before the photograph was taken.

The plant, being late in maturing and the herbage green and tender throughout the season, is grazed with much relish by all classes of stock from early spring until late autumn.

It occurs in dense stands only in small isolated patches and consequently is not highly important as a range plant.

SPIKED TRisetum.

(*Trisetum spicatum.*)

The genus *Trisetum* belongs to the oat tribe. and is represented by about 8 species in the western United States, most of which occur in the higher mountains.

The zonal distribution of *Trisetum spicatum* is typically Hudsonian, though it occurs commonly above timber line and is found to a limited extent on north and east slopes in the Canadian zone. The plant occurs irregularly in scattered stands throughout the upland ranges in exposed situations on well-drained soils. It is frequently associated with slender hair-grass, but is more deeply rooted. As its habitat indicates, spiked trisetum is not readily killed by drought. Most specimens tested were able to regain turgor and, of course, absorb water from the soil until its content was reduced to from 7.5 to 9.5 per cent. As a rule the plants died very gradually, probably owing to the highly developed contrivances for protection against rapid transpiration.

The plant is a perennial of tufted habit with deep and widely spreading fibrous roots (Plate XIV). It may usually be recognized by the soft downy pubescence on the sheaths and culms, which has given it the local name "wool grass," although this is a widely variable character, some individuals appearing nearly smooth. Most specimens appear downy silvery white. The culms vary in height from 1 to 2 feet. From the crown arise a large number of short, flat, and rather wide basal leaves. The panicle is spikelike and cylindrical in character, somewhat contracted and shiny. The lemma or flowering glume bears on the back a rather inconspicuous, slender, soft, divergent awn.

The flower stalks appear about July 10, and a month later production is usually complete. The seeds do not begin to ripen before about August 25, and generally are not all matured by the time inclement weather comes in the fall and prevents further development. As a result, viable seed are produced only on the earliest flowering stalks. In 1907 the seed crop averaged 11 per cent germination, and in 1909, 28 per cent. No tests were made in 1908.

While spiked trisetum occurs in scattered stands, it is widely distributed and furnishes more forage than is ordinarily thought. The leaf blades are eaten in preference to many other species, so that little

of the herbage goes to waste. In addition, the plant begins to grow early in the spring and does not ripen until late in the fall, so that it remains fresh and palatable throughout the season. Though it withstands trampling well, natural regeneration on protected ranges is scant as compared with that of other species whose seed crop has about the same or even lower viability.

MOUNTAIN JUNE GRASS.

(*Koeleria cristata*.)

Koeleria, though a genus of only about 15 species, has wide geographical distribution. In the United States mountain June grass is the only representative of common occurrence and much economic value.

Mountain June grass is a tufted perennial species, 1 to 2 feet in height, the culms of which are usually pubescent just below the panicle. The leaves, which are mainly basal (Plate XV), are unusually numerous. They are flat or slightly inwardly rolled, vary in texture from smooth to rough, and are often hairy. The panicle, pale green in color, is spikelike when young, but during fertilization is rather widely expanded. The lemmas or flowering glumes are glossy, and the plant can nearly always be recognized off hand by the shiny character of the panicle.

This plant often inhabits very dry situations, though on the lower ranges it matures comparatively early and so largely avoids the driest part of the season. In the higher altitudes moisture is usually present a few inches below the surface. Most of the plants tested wilted strikingly, usually beyond recovery in a soil having from 10 to 13.5 per cent water content. Thus the soil-moisture requirements in the particular soil type in which it grows are about the average.

The flower stalks on the upland ranges were put forth in 1907 between July 10 and 28; in 1908 between July 10 and 25; and in 1909 between July 5 and 25. The seeds begin to ripen about the latter part of the second week in August, but the entire crop is not matured until about September 10.

The germinative power of the seed is low. In 1907 an average of three tests gave 16 per cent and in 1908 14 per cent. No test was made in 1909. However, on the lower areas in the Transition zone, for example, the seed was somewhat more viable, though there was no marked contrast in the germinative power.

Mountain June grass is of considerable importance as a forage plant in the region studied, and few species are more eagerly eaten. The long, soft, and numerous crowded basal leaves are consumed by sheep, cattle, and horses in preference to many more abundant forage plants when green, and, like mountain bunch grass, the leaf blades but not the flower stalks are eaten by sheep after the seeds have reached ma-



SOFT CHEAT OR CHESS (*BROMUS HORDEACEUS*).

F-19Q



TALL MEADOW-GRASS (*PANICULARIA NERVATA*).

turity. It is found rather sparingly on the higher ranges, but is fairly abundant in glades and sparsely timbered areas of medium moisture in both the Canadian and Transition zones.

ONION GRASS.

(*Melica bella*.)

The species of the genus *Melica*, over 50 of which have been described, are distributed throughout the temperate and subtropical regions. Several are of value for grazing, but the genus as a whole, contains few species of high economic importance.

Onion grass enjoys a rather wide distribution, growing luxuriantly in the upper Canadian zone, but also succeeding well in the Hudsonian zone. It rarely occurs as the predominating species in a plant formation, but appears in rather scattered stands in association with such species as mountain bunch grass and short-awned brome grass, on well-drained soils. In its ability to exist in soils of low water content it is very similar to mountain bunchgrass, the plant wilting beyond recovery from this condition when the soil water is reduced to from 6.3 to 8.5 per cent.

Onion grass is a perennial, bulbous at the base, fibrous rooted (Plate XVI). Culms 1 to 2 feet tall, sheaths and blades smooth or slightly rough to the touch. The panicle is sparsely branched, and the spikelets usually bear 5 flowers. The lower or empty glumes are shorter than the scale of the floret, and both the glumes and the lemma, especially the part of the latter naturally exposed, are dark purple when young, fading to light brown upon the approach of maturity.

The flower stalks appeared from July 20 to August 10, in 1907, July 15 to August 15 in 1908, and July 10 to August 15 in 1909. In 1908 matured seeds were not found until August 20, and in the other two seasons the seed-maturing period was even later; in fact, this function was so much delayed in many situations, particularly where grazing had been carried on excessively, that a large amount of the seed failed to mature at all.

Germination tests showed the seed to have a low vitality. In 1907 negative results were obtained, and in 1908 only 4 per cent germination was secured. In 1909 no germination test was made. From these data and the fact that it is not regenerating on the range, the species would seem poorly adapted to the revegetation of depleted ranges.

Notwithstanding the fact that onion grass has a wide distribution and ranks high in palatability, its scattered growth restricts its value as a forage plant. It starts growth early in the spring and, since it continues activities until late in the season, is relished throughout the summer by all classes of stock, and especially by sheep.

A species of the same common name, closely resembling *Melica bella* and nearly as widely distributed and as important economically in the region studied, is *Melica spectabilis*. In habit of growth and general appearance the plants are very similar, both being bulbiferous and growing to practically the same height. In contrast with the rather dull spikelets of *M. bella*, however, those of *M. spectabilis* are bright in appearance and the glumes are membranaceous; the pedicels of the former are stiff and erect, whereas those of the latter are slender and flexuous. The period of flower-stalk production and seed maturity is virtually the same as in the case of *M. bella*, and the viability of the seed crop is also very low.

LITTLE BLUEGRASS.

(*Poa sandbergii*.)

The genus *Poa* is composed of about 150 species widely distributed in temperate and cold regions. In the western United States about 75 species have been reported. The value of the bluegrasses for hay and forage is well known. Cultivated Kentucky bluegrass is closely related to little bluegrass.

Little bluegrass is distinctly a plant of the Transition zone, though through its ability to adjust itself to more or less adverse conditions it succeeds remarkably well on upland ranges and furnishes an abundance of forage. While at higher elevations it often grows luxuriantly in rich clay loam soils, usually it inhabits inferior shallow soils. On typical scablands and rocky areas it is the most common and characteristic species. Owing primarily to its ability to withstand drought and wide variation in temperature, the range of distribution of little bluegrass in the region studied is unusually broad. It grows profusely in the lower limits of the Transition zone, about 2,000 feet, and is also common on ranges of 8,000 feet elevation. On such situations it is almost invariably confined to scablands and poorly disintegrated soils on the warmer south and west exposures. In the tests made to determine its drought resistance, little bluegrass did not show signs of complete wilting until the soil water was reduced to between 6.5 and 7.8 per cent.

Little bluegrass is a perennial (Plate XVII) and grows in tussocks not usually exceeding 8 inches in diameter. It has coarse, deeply penetrating roots, which withstand trampling remarkably well; smooth culms, slightly decumbent at the base, $1\frac{1}{2}$ to 2 feet in height; close erect panicles composed of spikelets of 3 to 5 florets; and a superabundance of narrow, short, and rather flat, or sometimes slightly folded, blue-green basal leaves.

The flower stalks of little blue grass are among the earliest to appear on the range. This is due, first, to the character of the situations in



BIG BUNCH GRASS (*AGROPYRON SPICATUM*).

F-210



MOUNTAIN WHEAT GRASS (*AGROPYRON VIOLACEUM*).

F-22Q

which the species grows on the higher ranges, and second, to the inherent tendency of the species to complete its development at a very early date in its lower zone. The flower stalks on the upland ranges appeared from July 10 to August 1, July 10 to August 10, and July 5 to August 5, in 1907, 1908, and 1909, respectively. The seeds began to ripen in the latter part of July, and, except in 1907, the seed crop had matured by August 20.

The seed crop developed in the high mountains has a low vitality, the average for all tests made for the Hudsonian zone for the three years being only 7 per cent. In contrast to this, seed grown in the Transition zone showed average germination of 38.4 per cent.

As a forage for sheep, horses, and cattle early in the season, little bluegrass can hardly be surpassed. The entire plant is readily consumed until the seeds begin to reach full development. After the seeds have matured, however, which they do early in the summer, the plant is neglected for the more palatable tender species. In the fall of the year, when the bulk of the range plants are air-cured, little bluegrass again becomes one of the choice species.

Other bluegrasses occur in the mountains, but as a rule are so scattered as not to merit special mention. The species most commonly met with, in order of their abundance, are *P. brachyglossa*, *P. paddensis*, and *P. ampla*.

SHORT-AWNED BROMEGRASS.

(*Bromus marginatus*.)

The genus *Bromus* is closely related botanically to *Festuca*, to which mountain bunchgrass belongs. In general, it differs in having larger spikelets and a toothed apex on the lemma, or flowering glume.

Short-awned bromegrass (Plate XVIII) is a perennial species, and on favorable situations almost invariably forms a dense turf. The culms are erect and stout, from 3 to 4 feet in height, the sheaths are usually clothed with scattered, rather long, soft hairs; the panicle is erect and somewhat narrow, of a purple cast, and from 4 to 8 inches long, with seven to nine flowered spikelets, the florets coarsely pubescent, with two rather pointed hyaline teeth at the apex and the midrib extending into an awn one-fourth inch long.

Short-awned bromegrass has rather a wide distribution in the region studied, but grows most luxuriantly between 4,000 and 7,500 feet elevation, where it generally inhabits the better soils of medium moisture content.

It grows in dry situations on open plateaus, in friable loam soils, and in canyons, and often predominates on the banks of streams. The plant did not wilt destructively until the moisture in the soil was reduced to between 5.5 and 8 per cent.

The flower stalks begin to show about July 25, and by August 10 are usually all produced. Matured seeds have been observed as early as August 10, and are usually pretty well ripened by September 1. Dissemination takes place almost immediately upon maturity.

Seeds of this species are above the average in germinating power. Seed vitality for the three years beginning with 1907 was 38, 47, and 58 per cent, respectively. On the lower ranges a germination as high as 85 per cent was obtained.

The forage value of short-awned brome-grass is relatively high. Because of its rank growth and the coarseness of the culms, however, it is more valuable for cattle and horses than for sheep, although if grazed when young the latter class of stock often entirely consume it. At a later period of growth the culms develop an abundance of crude fiber, and sheep then consume only the leaf blades and the panicle with its spikelets of developing grain. Horses are particularly fond of the grain both in the matured state and when green, and stockmen consider it equal to oats in nutritiousness. When this species is grazed off early in the summer it continues to grow luxuriantly, and at the close of the season has produced a second crop of leafy foliage equal in palatability to the early crop. Under such treatment, however, no seed stalks are produced.

On the Wallowa National Forest a variety of short-awned brome-grass, *B. marginatus seminudus*, and three other species, namely, rattlesnake grass (*B. brizaeformis*), *B. richardsonii*, and soft cheat (*B. hordeaceus*) have been collected. Because of the sparseness of all these forms except the last, this will be the only one discussed.

SOFT CHEAT.

(*Bromus hordeaceus*.)

Soft cheat or chess, an annual native to southern Europe, has taken possession of deteriorated grazing lands in Washington, Oregon, and certain localities in California. On the lower ranges of the Wallowa National Forest, where germination occurs in the fall, it produces a first-class early spring feed when little else is available.

Soft cheat (Plate XIX) has an erect growth. The culms, which are often very hairy at the nodes, attain a height of from 1 to 2 feet and are subtended by sheaths bearing long flexible hairs often of a silvery-white luster. The leaves are long and narrow, somewhat pubescent or smooth, and rather numerous for an annual species; the panicle is narrow, contracted, and erect, the spikelets from 5 to 13 flowered. Extending from the lemma or flowering glume is a stout, straight, or when old, slightly twisted awn, about $\frac{1}{2}$ inch long, somewhat flattened near the base.

Soft cheat is well adapted to the Transition zone, but grows luxuriantly in the Canadian zone, and is occasionally met with in



RED BUNCH GRASS (*AGROPYRON FLEXUOSUM*).

F-230



SMOOTH WILD RYE (*ELYMUS GLAUCUS*).

F-240

the Hudsonian zone, though there it is of little forage value. It makes its best growth on shallow clay loam soils, where, notwithstanding its shallow roots, it remains green throughout the summer. External hairy contrivances protect the plant from transpiration.

Wilting beyond recovery does not take place until the soil moisture falls to or slightly below 5.5 per cent, a condition which very few herbaceous species can withstand. Owing to its ability to succeed in dry soils and to withstand long periods of drought, and because of its good seed habits and aggressiveness, soft cheat is valuable as a binder for exposed soils.

On the higher ranges in the Canadian zone, and in those parts of the Hudsonian where it occurs, the flower stalks are mostly produced by July 15. The seeds are usually matured by August 10. In the Transition zone the seeds are ripened a month earlier. Seed collections made on the upland ranges at an altitude of 6,000 feet yielded an average germination of 48.2 per cent, while seed grown in the Transition zone during the same seasons averaged 78.5 per cent. This wide difference is doubtless due to the more favorable temperature in the lower zone.

Since the forage of soft cheat is produced exceptionally early, it is of special value at that season, and the leaf blades are then eagerly eaten. There is diversity of opinion among stockmen as to the nutritive qualities of this grass. Many claim that it is a valuable feed when supplemented with other species of grasses and weeds, but owing to its "washy," succulent nature in the spring of the year, it is not conducive to putting on solid fat. Miners say that their pack animals fatten quickly upon it when left at leisure, but when grazing upon it exclusively they are unable to work without excessive loss of flesh. After the seeds have ripened the plant is of very little forage value.

TALL MEADOW-GRASS.

(*Panicularia nervata*.)

The genus *Panicularia* belongs to the same tribe as Kentucky bluegrass and mountain bunch grass. It contains about 20 species, most of which are found in North America. As its common name implies, tall meadow-grass usually attains a good height. The leaf blades are flat, smooth beneath, and rough above, and the sheaths are rather rough throughout. At maturity the somewhat purplish panicles with long flexible branches are usually drooping.

This species is closely confined to moist situations, and is able to thrive in rather deep shade. It is almost invariably associated with slender reed-grass and various species of sedges and rushes of high water requirements. It occurs rather extensively in moist situations in the Canadian zone, and is often the chief species in favorable spots in both the Hudsonian and Transition zones.

Since tall meadow-grass is entirely restricted to wet soils, the root system is not extensively developed, and it requires a relatively high amount of moisture to supply its needs. In its typical habitat it wilted beyond recovery when the soil water was reduced to from 12 to 14.5 per cent.

The average period of flower-stalk production extends over about three weeks, beginning about July 10, while by August 1 most of the stalks have been sent forth. The seed begins to ripen about August 20, and by September 10 the crop is practically all matured and disseminated. Seeds are dropped immediately upon ripening.

The germinative power of the seed crop, as tested in 1908, gave an average of 85 per cent, and since reproduction of this species seems to be generally good, it is probable that the seed has a high average vitality.

Tall meadow-grass (Plate XX), like a number of other species with a high-water requirement, supplies only a limited amount of forage. It is relished by all classes of stock, and is probably most valuable as forage during August, since it is then less succulent than earlier in the season. Up to August 1 the flower stalks are eaten nearly to the same extent as the leaf buds, but after that period they become somewhat tough and are not usually eaten by sheep. Horses and cattle, however, continue to consume the entire plant until much later in the season.

Another species, *P. pauciflora*, very commonly associated with tall meadow-grass, has similar distribution and habits. *P. pauciflora*, however, does not occur as abundantly and, consequently, is not as valuable as a forage plant. It is readily distinguished by having 5 nerves on the lemma instead of 7, as in the case of tall meadow grass.

BIG BUNCH GRASS.

(*Agropyron spicatum*.)

The grass tribe, *Hordeae*, to which this and the following five species belong, is of high importance in the West. The genus *Agropyron* contains about 40 species, more than half of which are found in the United States. Of these, many are highly valuable for hay and forage.

Big bunch grass or blue bunch grass, as it is sometimes called because of the characteristic blue-colored culms or stems, is a perennial with deep fibrous roots. The culms, smooth and covered with "bloom," attain a height of about 12 to 18 inches in dry situations where this grass characteristically occurs, while in deep rich soils of abundant moisture a height growth of about 30 inches is sometimes made. The leaf blades, about half the length of the culm, are mainly basal and produced in abundance. They are flat when green, but slightly rolled inwardly when the plant is air dry or suffering for lack



WHITE FOXTAIL (*SITANION VELUTINUM*).

F-28Q



TALL SWAMP SEDGE (*CAREX EXSICCATA*).

F-26Q

of water. The spikes are somewhat compressed, slender, 2 to 4 inches long. The spikelets are flattened, and as shown in Plate XXI, are long, narrow, erect or spreading, 3 to 6 flowered, 4 to 12 in number. The glumes (empty lowermost two scales) are sharp-pointed but awnless; lemmas (upper flowering scales) are usually provided with stout, somewhat twisted awns $\frac{1}{2}$ to 1 inch long.

The distribution and abundance of this grass are unusual. It constitutes the controlling type of plant growth below the yellow-pine zone, where it is depended upon to furnish the major portion of the fall, winter, and spring forage. In a few localities in Montana and Wyoming it grows so dense that it is of value for hay. It extends even into the Hudsonian zone (usually in scattered stand, though in favorable situations nearly covering the ground with a rank growth), and even in this grazing type produces considerable herbage. This wide distribution is due to its remarkable capacity to endure drought. It is able to exist though for several days in a wilted condition, in the basaltic-soil type of the higher ranges when there is but 5.5 to 7.5 per cent water. This accounts for the prevalence of big bunch grass on scablands, benchlands, and gritty, poorly disintegrated soils of low water content.

Flower stalks first show about August 1, appearing very irregularly until perhaps September 1. Both the beginning and completion of production are thus unusually late, and the delay in the appearance of the flower stalks is reflected both in the time of seed maturity and in the fertility of the seed. Fully ripened seeds are rarely found before August 20. The seed crop continues to ripen irregularly as long as the weather permits, but the bulk of the seeds do not reach maturity. The seed that does mature germinates rather poorly. The average for 1907, 1908, and 1909 was 16, 30, and 26.5, respectively. On the lower ranges, however, seed is matured early and evenly, and a germination of 80+ per cent is often obtained.

The large amount of herbage afforded by big bunch grass on the lower ranges, and even in the upland grazing areas, places it well toward the top of the list of important forage plants. No other grass or forage plant is so abundant on the lower areas, nor supplies so much feed. As a fall, spring, and winter feed it is preeminent. When the fall rains come on, usually in September, big bunch grass is awakened to growth, and for two months or more, depending upon the altitude and physiography, continues its activities. This tender and succulent herbage is ravenously consumed by all classes of stock in the fall as well as during the winter and spring. About the middle of June on the lower areas, however, the foliage becomes somewhat tough and unpalatable and ceases to be of high value for forage. On the higher ranges, owing to the delay in the growing period and the absence of growth in the fall, the plant is grazed

throughout the season, though it does not seem to be consumed with the same eagerness as many other species.

MOUNTAIN WHEAT GRASS.

(*Agropyron violaceum.*)

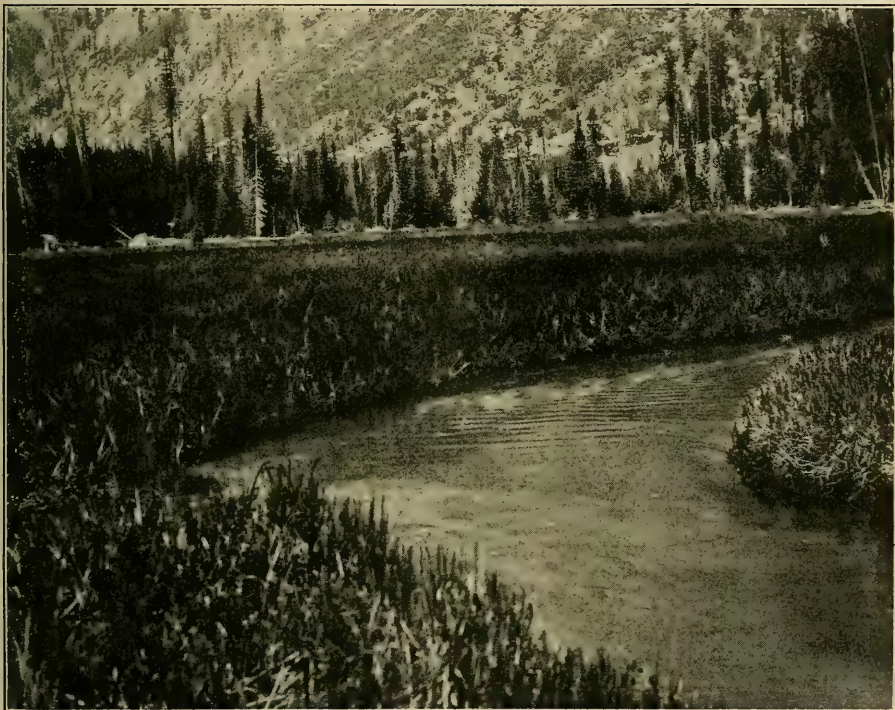
Mountain wheat grass resembles in general appearance cultivated wheat, though the two are not closely related botanically. Like big bunch grass, this species is a densely tufted perennial with deep and spreading roots. It is readily distinguishable from the former species, however, by its awnless spikelets or the presence of a slight rudimentary awn on the lemma. The leaves are unusually numerous, basal, flat, and somewhat rough, about half the length of the culms, the latter attaining a height of from 1 to 2 feet. The spikes are slender and short, the lower (empty) glumes being conspicuously three-nerved (Pl. XXII).

Though common in both the Canadian and Arctic-alpine zones, this species reaches its best development in the Hudsonian zone. As would be expected from the extensive development of the root system, it is best adapted to soils of medium moisture content. It inhabits open exposed situations, and is usually associated with big bunch grass, mountain bunch grass, and little bluegrass. In ecological requirements it resembles these species closely. In the drought tests it did not wilt beyond recovery until the soil water dropped to between 6 and 7.5 per cent.

The flower stalks begin to show during the last week of July or first days of August, and production is for the most part complete within 3 weeks after their first appearance. As a rule the seeds are ripened from about August 20 to September 1. Dissemination takes place almost immediately after maturity.

As a rule, the vitality of the seed of most of the species growing in the Hudsonian and Arctic-alpine zones reaching maturity on or before September 1 is high, and in this respect mountain wheat grass is no exception. In 1907, a very poor seed year for mountain wheat grass, there was an average germination of 78 and in 1908 and 1909, respectively, an average of 96 and 82.5 per cent. From these figures it would be expected that this species is regenerating in favorable localities. Observations show that this is true where the seed crop is worked into the soil through grazing or otherwise, but where the surface layer is undisturbed the seeds, which are large and have no awns on the flowering scales to bore them into the ground, do not germinate.

Mountain wheat grass is greatly relished by all classes of stock. Growth starts promptly in the spring, and the plant remains green and palatable until late in the fall. It is eaten with the greatest relish



F-27G

TALL SWAMP SEDGE IN A SATURATED SOIL ON MINAM MEADOWS, WHERE IT FINDS AN IDEAL HABITAT.



SHEEP SEDGE (*CAREX ILLOTA*).

F-28Q

up to about August 15, but considerably later in the season, even in September, the basal leaf blades, though not the flower stalks, are eaten close to the ground by sheep and cattle. Mountain wheat grass is cropped in preference to a large number of species. It is preferred in the latter part of the season, if not earlier in the year, to big bunch grass, though its scattered growth and narrow zonal distribution make it less important than the latter.

A species closely allied botanically to mountain wheat grass is red bunch grass (*A. flexuosum*), so named on account of its reddish-purple panicles and bunched habit of growth (Pl. XXIII). Its prominent awns and loose spikes, however, give a very different appearance from the former. It is sometimes mistaken for smooth wild rye (Pl. XXIV), though very different in structure. In its range of distribution, ecological requirements, period of flower stalk production and seed maturity, and in its forage value, red bunch grass is very similar to mountain wheat grass, though in most situations it does not remain palatable as late in the season.

SMOOTH WILD RYE.

(*Elymus glaucus*.)

The species belonging to this genus are generally known as rye grasses because of their resemblance to the ordinary cultivated rye. There are about 25 species of *Elymus*, distributed mainly throughout the north temperate regions.

Smooth wild rye is a perennial bunch grass with a strong root system capable of withstanding more than the average trampling by stock. It grows from 1 to 3 feet in height, the sheaths enveloping the culms usually being smooth, the leaves abundant, smooth beneath, sometimes rough above. The spike, 2 to 5 inches long, is narrow and slender, bearing numerous spikelets of three to six flowers. The glumes (lowermost empty two scales) are narrow, sharp pointed and rigid. The lemmas (upper flowering scales) smooth or slightly rough, each bearing a straight rough awn one-fourth to one-half inch in length.

This grass is distributed over a wide altitudinal range. It is most abundant in the upper Canadian zone, is fairly common in the lower Hudsonian zone, and is found to a limited extent in the Arctic-alpine zone. As a rule, its growth is not dense, but affords an abundance of forage because of its wide distribution. In most cases it is merged with mountain bunch grass, short-awned brome grass, and other species characteristically associated with the latter in glades and parks. Smooth wild rye seems to be somewhat better able to succeed in moister habitats than many of the plants associated with it in exposed situations, and yet it withstands drought remarkably well. In the drought tests it did not wilt beyond recovery in some

instances until the soil moisture was reduced to 7.5 per cent, though two species died when there was a water content of 9.8 per cent.

Flower stalks begin to appear during the first week in July and continue until about the first week in August. The seed crop begins to ripen as early as August 1 and continues throughout the month, few immature seeds being found in September. The vitality of the seed crop is about the average for upland grazing plants. The average germination for the three years of study was 21.2 per cent. From this it would seem that many other species, such as mountain wheat grass, which shows an average germination of 64 per cent, would reproduce much more abundantly. Smooth wild rye, however, is one of the most aggressive species on the high grazing lands. The seedlings develop deep root systems, and a large percentage of the young plants succeed in rather adverse situations.

The grazing value of smooth wild rye is high. By many stockmen the plant is considered rather too coarse for sheep, though it is probable that its forage value in this respect is underestimated, since observations show that sheep readily graze it. Sheep rarely crop the flower stalks, because these are produced exceptionally early, and their rapid height growth soon puts the best part of them out of reach of the animals, and because the stalks are somewhat coarser than sheep relish and become unpalatable early in the season. All things considered, however, this plant furnishes good forage by the time the upper ranges are grazed, and the herbage is consumed ravenously throughout the season. Horses are fond of the flower stalks, and until the seeds are matured and disseminated the spikes or flower heads also furnish choice feed. Cattle graze the forage closely even after the seed has been disseminated.

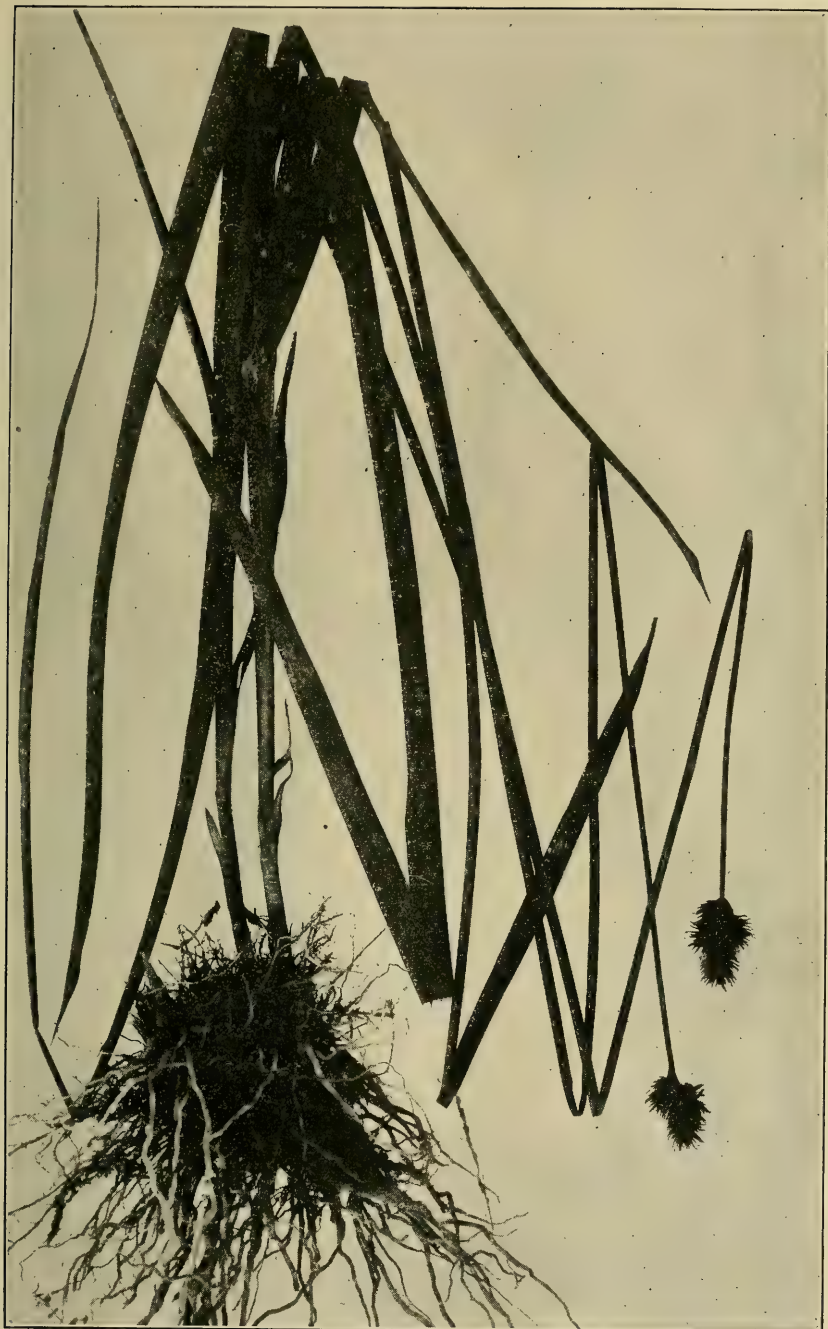
WHITE FOXTAIL.

(*Sitanion velutinum.*)

White foxtail, often called wild barley, to which it is closely related, is undesirable on the range because of its low forage value and its aggressiveness on overgrazed areas.

The plant derives its name from the prominent awns, which, with the entire spike, turn a light-straw color upon reaching maturity. It is a tufted perennial grass from 1 to 2 feet tall, the culms rather conspicuously spreading on the ground, the leaf blades mainly basal, somewhat involute and rough, the upper surface pubescent. The glumes are provided with long stiff awns, which, at maturity, are strikingly divergent (Plate XXV).

White foxtail is most abundant in the Hudsonian zone. It is also found on the lower grazing types, though not to the same extent as on upland ranges. The situations most favorable to it are open glades of rather poorly disintegrated soils with moisture content



MARSH OR WATER SEDGE (*CAREX FESTIVA*).

F-29Q



below the average. In the drought tests the individual plants wilted excessively in soil varying in moisture from 6 to 8.5 per cent.

The flower stalks of white foxtail are among the earliest to appear, and are practically all produced by August 1. Matured seeds are found as early as August 15, and are practically all ripened by the end of the first week in September. Unlike most species, the seeds are not disseminated immediately upon reaching maturity, but persist for some time unless they are brushed off by direct contact or shaken off by some vigorous mechanical means. Wind is ineffective in bringing about a wide distribution of the seed, but stock, especially sheep, when they come in contact with matured plants, distribute the seed crop broadcast, the awns attaching themselves to the wool.

Germination tests as well as observations on the reproduction of this plant on the range indicate a high viability. In 1907 and the two succeeding seasons an average of 43, 77, and 82.5 per cent of the seed germinated under controlled conditions. The best reproduction is taking place on sparsely vegetated soils where the seed are worked well beneath the surface and where competition with other species is not severe.

The forage value of white foxtail is always low. In the spring, shortly after growth has started, the leaf blades are eaten by stock of all kinds, but this period is so short as to be negligible. Even before the majority of the flower stalks are produced the herbage becomes tough and harsh, and stockmen claim that the mouths of sheep become sore and tender if they graze it to any extent. As soon as the seeds begin to ripen white foxtail is almost wholly disregarded. If stock should consume any quantity, however, the awns may cause sore mouths and big throats, and the barbs even get into the eyes. Thus the plant is practically worthless, and the range would be better off by its absence.

GRASSLIKE PLANTS.

DISTINCTIONS BETWEEN GRASSLIKE PLANTS AND GRASSES.

Stockmen, as a rule, do not distinguish between true grasses and grasslike plants such as sedges and rushes. The latter, because of their frequent occurrence in marshes, swales, along creek banks, and in other moist situations, are commonly referred to as "water grass," "wire grass," "swamp grass," etc., but the three distinct groups of grasses, sedges, and rushes are almost invariably spoken of collectively as "grasses."

Sedges, *Carex*, may readily be distinguished from grasses in the following simple ways:

1. The stems of sedges are triangular, jointless and solid, the leaves 3-ranked, and the leaf sheaths closed.

2. The stems of grasses are generally hollow, cylindrical, and jointed, the leaves 2-ranked, and the leaf sheaths usually split.

Rushes (*Juncus* and *Juncoides*) are readily distinguished from grasses and sedges by:

1. The flowers of rushes are regular and, though diminutive, similar in form to those of a lily, having a perianth composed of six bractlike scales, and with three to many small seeds borne in a capsule or small pod.

2. The flowers of grasses and sedges are not symmetrical, the perianth being irregular and inconspicuous or obsolete, and are subtended by husklike scales, each flower producing but a single seed.

SEDGES AND RUSHES.

It is the general opinion among ranchers that, as compared with grasses, sedges and rushes are of low nutritive value. This idea is generally true, but when a grass species occupying a typical marshy bog is compared with sedges and rushes from a similar situation chemical analysis has shown that the food value differs but little. Practically all species of moist habitats are somewhat too succulent or "washy," notably in the spring of the year, and while they are eaten with relish at that time they are doubtless more nutritious later in the season.

A thousand or more species of sedges (*Carex*) have been described. They are widely distributed and are most abundant in temperate regions. In the United States approximately 500 species are found, about half of which occur in the Western States. The rush genus (*Juncus*) contains over 200 species.

TALL SWAMP SEDGE.

(*Carex exsiccata*.)

Because of its abundance, density of stand, and height growth, this species is one of the best-known sedges on the Wallowa National Forest. It ranges from 1½ to 3 feet in height, has coarse leafy culms, and broad, thick, flat leaves of a light-green color. The spikes, developed sometimes as much as 4 inches below the staminate flower clusters, are very short-stalked (Plate XXVI). The root system is somewhat meager, and new growth takes place abundantly through stolons and rootstocks.

The drought tests showed that this plant wilted destructively when the rich organic soil in which it grows contained, in the one case, 22.5 per cent of moisture and in the other 24 per cent. Obviously, therefore, the species is distinctly of the marsh type. In most perennial bogs, preferably in saturated soils, it grows pure, to the exclusion of other species (Plate XXVII).



MARSH SEDGE (*CAREX TOLMIEI SUBSESSILIS*).



ELK GRASS (*CAREX GEYERI*).

F-329

In somewhat drier situations, such as over-irrigated meadows, it often produces a conspicuous growth, and when associated with some cultivated grass such as redtop, is cut for hay. Tall swamp sedge is most common in the Canadian zone, but also occurs along the border of the Hudsonian zone.

The flower stocks begin to push forth about June 20, and are all out by the last week in July. The seed are comparatively slow to mature, practically none being found until the last week in August, while the entire crop is not ripened until September 15. In viability the seed ranks low. The average germination obtained from the tests made in 1908 and 1909 (no tests made in 1907) was 15.2 per cent. Low vitality in the seed of this plant, however, is of little significance, since the species propagates profusely by rootstocks.

Compared with many other species of its class, the forage value of tall swamp sedge is high, and early in the season the herbage is eaten with relish by sheep. Owing to the sheep's dislike for bogs, however, many areas densely covered with this species are not visited until the soil becomes fairly dry. In the latter part of the summer the leaf blades become tough and harsh, and sheep do not consume them with the same eagerness as in the forepart of the season. Horses are particularly fond of this plant. They graze it throughout the season and seem to do well upon it for short periods, but, if left free, withdraw to better-drained soils which afford a wholly different type of herbage. Miners and campers state that their pack animals eat tall swamp sedge readily, but are unable to do the usual amount of work when grazed exclusively upon it. It is probable, therefore, that its nutritive value is low.

SHEEP SEDGE.

(*Carex illota*.)

Of the bog forage plants of the genus *Carex*, sheep sedge is possibly the most important. It is a stoloniferous perennial or densely matted species about 1 foot tall, with culms usually exceeding by one-third the numerous grasslike leaves. The latter are narrow and smooth, and soft even when the plant is mature. Inconspicuous small spikes crowded into small dark brown heads distinguish it from certain other associated species (Plate XXVIII).

Sheep sedge is confined to mountain meadows, and rather closely to moist situations, though it persists in some which become comparatively dry later in the season. Conditions in the Hudsonian zone are well adapted to its highest development. The leaf blades wilted but recovered their form in the rich loam soil containing 14 per cent of moisture.

The flower stalks begin to appear about the middle of July and are practically all sent forth during the following three weeks. Matured

seeds are found about August 20, and by the end of the first week in September the whole seed crop has ripened. Data on the vitality of the seeds were obtained only in 1909, when an average from three tests gave 27.5 per cent germination.

As its common name implies, sheep sedge is a highly relished sheep forage. The leaves are tender and juicy throughout the summer, and the plant seems to be consumed with about the same eagerness at all times during the growing season. Horses, too, graze this sedge with unusual eagerness, consuming flower stalks with the same avidity as the leaf blades. Since sheep sedge is restricted to moist habitats it is, of course, not very abundant, but in favorable situations it holds its own remarkably well, and it is not uncommon to find it predominating over other sedges and more fastidious species almost to their entire exclusion.

Three other species, usually called marsh or water sedges, *C. festiva*, *C. vulgaris bracteosa*, and *C. tolmiei subsessilis*, are, on account of their general appearance, forage value, and distribution, often confused with sheep sedge. Of these, *Carex festiva* resembles it most, but differs in many minute characters (compare Plates XXVIII and XXIX). The leaves of *Carex festiva* are much broader and coarser, and are rough on the edge, and the color of the plant is light green. The other two species, *C. tolmiei subsessilis* and *C. vulgaris bracteosa* (Plates XXX and XXXI) have much more elongated spikes, of a brown-black color, which alone should eliminate confusion. The latter attains about twice the height of the former, and its culms are more acutely angular. The forage value of all three species is practically the same, though *C. vulgaris bracteosa* is relatively less abundant than the other two. *C. tolmiei subsessilis* remains palatable to stock for a longer period than either of the others, but is more abundant in the alpine or upper subalpine regions, and therefore matures later, being of little importance as forage when the other species are of highest value.

ELK GRASS.

(*Carex geyeri*.)

Of the dry-land sedges, elk grass is by far the most abundant. It occurs in the Canadian and Hudsonian zones, often as the predominating species on exposed hillsides, and is among the earliest of the herbs to send forth its leaf blades. Many hillsides have been almost wholly vegetated by this species.

Since elk grass produces new plants by stolons the growth is dense and segments of a tuft are almost inseparable (Plate XXXII). The slender, angled, rough culms, about 1 foot high, exceed but slightly the harsh and rough-edged leaf blades. The spikes are slender, borne at the summit of the culm, the staminate flowers usually appearing above, and the pistillate (1 or 2 in number) below.



RUSH (*JUNCUS PARRYI*).

F-33G



WOOD RUSH (*JUNCOIDES PARVIFLORUM*).

F-340

The very nature of the habitat in which elk grass succeeds indicates its unusual ability to withstand low moisture conditions. The soil in which it grows is a coarse gravelly one, which liberates the water more readily than finer soils. Drought tests resulted in the extensive wilting of all leaf blades of the plant only when the water content was reduced to 6.5 per cent, and in some instances slightly lower. This places elk grass very near the head of the list in its ability to exist under adverse moisture conditions. Flower stalks begin appear during the last week in June, and by July 20 practically all are out. About the time that the last flower stalks are sent up matured seeds are found. By August 15 the seed crop is almost entirely ripened and disseminated. The seed has about average viability, the tests in 1907 and in the two subsequent seasons showing germinations of 6, 26, and 32 per cent, respectively.

In the forefront of the season elk grass is grazed with a certain amount of avidity, though practically every other grass species is preferred to it. It is only eaten by sheep up to about August 1, unless the stock are starved. After that date the leaves become so tough, hard, and fibrous that even horses will not graze it if other forage is available. Sheep always scatter widely when feeding upon it, doubtless searching for more palatable food.

RUSH.

(*Juncus parryi*.)

Among the several species of rushes found on the highland ranges *Juncus parryi* is commonly met with, and in value is typical of other species which are abundant in the region studied.

Like most rushes of the drier situations, *Juncus parryi* is tufted, and has woody, fibrous, deep-spreading roots capable of withstanding an unusual amount of abusive grazing. The stems are thin and wiry, from 4 to 10 inches long, and the cylindrical leaves are about half the length of the flower stems (Plate XXXIII); the inflorescence, usually 2 or 3 flowered, is surpassed by a bract similar to the leaves.

Juncus parryi is confined to the high ranges. In the Hudsonian zone it occurs extensively in open, exposed situations on well-drained, often poorly disintegrated soils. It is usually associated with elk grass (*Carex geyeri*) and is just about as drought resistant, the specimens studied not wilting beyond recovery until the soil-moisture content was reduced to from 5.5 to 7 per cent. Above timber line it is found in considerable abundance in association with typical alpine species.

On the lowest areas on which the plant occurs the flower stalks begin to show about July 10, and by August 5 nearly all have been sent up. Matured seeds are usually not found before August 25.

The viability of the seed crop has not been determined. Other species of the same genus growing in similar habitats have given results that are comparatively low. (See Table 2, p. 58.)

The forage value of *Juncus parryi* is not especially high, resembling that of elk grass more than any of the other species described. Like the latter, this rush is eaten to some extent early in the season, but soon becomes extremely tough and unpalatable. For this reason, if other forage is available, it remains untouched by horses and sheep. Since it is grazed to such a limited extent, practically nothing is known of its nutritive qualities.

A number of other rushes of minor importance occur throughout the mountains, the majority in moist soils.

WOOD RUSH.

(*Juncoides parviflorum*.)

This genus is closely related to the rushes and resembles them in general character. It may be distinguished from the latter, however, by the leaf sheaths, which in this genus are closed and in the rushes open. Further, the seed vessel or capsule of *Juncoides* bears 3 seeds while in *Juncus* the capsule is many-seeded. About 60 species are on record and they are widely distributed.

Wood rush is a tufted, hardy, perennial plant, the stems, commonly 2 to 3 in a tuft, 1 to 2 feet high. As shown in Plate XXXIV, the grasslike flat leaves, usually about one-third the length of the flower stems, are wide and sharp-pointed; inflorescence a loose panicle, commonly $2\frac{1}{2}$ to 4 inches long, its lowest bract foliaceous, usually less than $\frac{1}{4}$ the length of the panicle; flowers borne singly or 2 to 3 together on the branches of the panicle on slender pedicels or stalks.

Wood rush is strictly a high-range plant, and while found to a limited extent in the warmer situations of the Arctic-alpine zone it is almost entirely confined to the Hudsonian zone. The densest and most luxuriant growth occurs in the semihumid soils of exposed situations, though it is often found in considerable abundance both in well-drained soils and on forested areas. Its most common associate is tufted hair-grass (*Deschampsia caespitosa*) and black hair-grass (*D. atropurpurea*). In water requirements it is similar to the two species of hair-grasses, neither of which may be classed as highly drought resistant. It is usually unable to recover from a wilted condition in its natural habitat when the water content of the soil drops to between about 10 and 12.5 per cent.

Since the plant grows only on the higher and relatively moist soils, the flower stalks seldom begin to show until July 20. Three weeks later practically all have been produced. Matured seeds are found about the time that the last flower stalks are sent forth, though the



MOUNTAIN ONION (*ALLIUM VALIDUM*).

F-350



SMALL WILD ONION (*ALLIUM COLLINUM*).

F-36Q

main seed crop is not ripened until about September 1. The vitality of the seed, according to tests made in 1908-1909, is low, an average for the two seasons giving only 7.5 per cent. The plant regenerates vegetatively to a marked degree.

No local species of the family to which wood rush belongs compares with it in forage value, in which respect it is of much more importance than certain species of grasses. It is relished by all classes of stock, but because of being restricted to high mountain lands not usually accessible to cattle and horses it is grazed almost entirely by sheep. The relatively moist and cool soil which it characteristically occupies tends to prevent rapid early spring growth, such as is made by plants in the better-drained and warmer habitats. Wood rush is therefore eaten with avidity when other species of high repute, as forage plants, are well along towards maturity and eaten with little gusto. Both sheep and horses have been observed to graze the leaf blades with eagerness, in preference to certain grasses and forage weeds, late in September.

Wood rush is able to withstand an unusual amount of trampling and abuse in favorable habitats because of its density of growth. This is due not to a particularly deep-root system, but rather to the density of the roots which ramify through the superficial soil layer, binding it so firmly as to prevent exposure of the roots by trampling.

NONGRASSLIKE PLANTS.

Besides the grasslike plants included in the preceding discussion, there are a number of other plants which furnish a large amount of the most valuable forage on the upland ranges. All classes of stock prefer a variety of feed, and sheep probably utilize a greater number of species than any other class. During certain periods of the year and under certain conditions, even where there is an abundance of comparatively palatable grasses, their choice forage is made up almost wholly of weeds and browse. A band of sheep when passing somewhat hastily over a range which supports an admixture of grasses, sedges, rushes, weeds, willows, elders, and the like, first eat the tender weeds and leaves of shrubs, while the grasses are not grazed, except to a limited extent, until the other kinds of forage have been largely consumed. On many of the upland ranges on the Wallowa National Forest there is a superabundance of weeds and here and there a number of shrubs, and since these ranges are accessible in the main only to sheep, the areas supporting these nongrasslike species are very closely cropped.

Owing to the great variety of this class of feed and the large number of species grazed by sheep, only the species of first importance are discussed. These have been arranged in families and according to their botanical relationships.

Liliaceae.....	Lily.
<i>Allium validum.</i>	
<i>Allium platyphyllum.</i>	
<i>Allium fibrillum.</i>	
Melanthaceae.....	Bunchflower.
<i>Veratrum viride.</i>	
Salicaceae.....	Willow.
<i>Salix scouleriana.</i>	
Polygonaceae.....	Buckwheat.
<i>Polygonum phytolaccaefolium.</i>	
Geraniaceae.....	Geranium.
<i>Geranium viscosissimum.</i>	
Onagraceae.....	Evening primrose.
<i>Chamaenerion angustifolium.</i>	
Apiaceae.....	Parsnip.
<i>Ligusticum oreganum.</i>	
Polemoniaceae.....	Phlox.
<i>Polemonium pulcherrimum.</i>	
Vacciniaceae.....	Blueberry.
<i>Vaccinium membranaceum.</i>	
Menthaceae.....	Mint.
<i>Agastache urticifolia.</i>	
Scrophulariaceae.....	Beardtongue.
<i>Pentstemon procerus.</i>	
Caprifoliaceae.....	Honeysuckle.
<i>Sambucus melanocarpa.</i>	
<i>Sambucus glauca.</i>	
Valerianaceae.....	Valerian.
<i>Valeriana sitchensis.</i>	
Cichoriaceae.....	Chicory.
<i>Hieracium cynoglossoides.</i>	
<i>Agoseris glauca.</i>	
Asteraceae.....	Aster.
<i>Rudbeckia occidentalis.</i>	
<i>Achillea lanulosa.</i>	
<i>Senecio triangularis.</i>	
<i>Senecio columbianus.</i>	

MOUNTAIN ONION.

(Allium validum.)

Onions belong to the lily family. About 275 species have been described, and 40 or more are found in the western United States.

Mountain onion, an account of its abundance, size, and the relish with which it is eaten, is one of the most valuable of these plants. It usually attains a height of 1 to 2 feet. The bulbs differ from those of other local species in being narrow and much elongated. They are provided with a rose-white, delicate covering. The rootstocks are unusually stout, and the plant makes a bunched growth, producing a heavy, dense rose-colored or nearly white flower cluster (Plate XXXV). Mountain onion is restricted to the Hudsonian and timber-line regions. It belongs to the group of plants which require a moist or even wet soil throughout the year and occurs in wet meadows and springy places within the altitudinal limits of its range. The



FALSE HELLEBORE (*VERATUM VIRIDE*).

F-379



FIRE WILLOW (*SALIX NUTTALLII*).

F-389

One leaf is turned so as to show the venation and character of the under surface.

minimum soil moisture content capable of maintaining it was found to be between 14 and 16 per cent. As a usual thing this plant grows in close association with marsh sedges and rushes, though it frequently produces a dense growth that crowds out other species.

The flowers begin to unfold during the first week in July, and nearly all are out by the end of the first week in August. Unlike grasses, whose pollen is carried to the flower by the wind, flowers of this and other onions obtain their interchange of pollen mainly through the visits of insects. The seeds are comparatively late in maturing, seldom beginning to ripen before the last week in August, and unfavorable weather conditions often prevent ripening. The average germination of the seed crop in 1908 and 1909 was 37 per cent. Considering the lateness of the maturing period, these figures are above the average.

The palatability of the mountain onion as compared with that of other plants growing with it is pronounced. When sheep first visit an area containing this particular onion in association with sedges, rushes, and the usual plants of such habitats, the majority of the other species are almost wholly disregarded until the onions have been grazed off. Few, if any, of the marsh plants are eaten with more eagerness than mountain onion. The flowers are usually cropped first, but the long flat tender leaves are apparently consumed with about the same relish.

Several species of onion occur on the upland ranges, but they furnish only a small amount of the range forage, though eaten greedily by nearly all classes of stock. Of these species the small wild onion (*A. fibrillum*) is the most important. This is the earliest of the species, doubtless from the fact that it is almost entirely confined to scablands. It is a small plant (Plate XXXVI), usually not over 6 inches in height, and has a cluster of white flowers which are expanded shortly after the disappearance of the snow. It is valuable only as an early range plant, and by August 1, like most other onions in similar situations, completes its growing period, dries up, and disappears. Wild onion (*A. platyphyllum*) is another important high mountain form, very similar economically and ecologically to *A. fibrillum*.

One objection to grazing sheep upon onion is that the mutton is flavored by it. This objection is not serious, however, since the plants are usually grazed early in the spring when there is little or no output of mutton, and the flavor is soon lost when sheep are put upon other forage.

FALSE HELLEBORE.

(*Veratrum viride*.)

False hellebore, sometimes known erroneously as skunk cabbage, is a close relative of the lilies. In appearance it resembles the true hellebore (*Veratrum album*), from which it derives its common name.

False hellebore is a perennial herb, $1\frac{1}{2}$ to 6 feet tall. Just beneath the ground the stalk becomes fleshy and much expanded, and from this protrudes a number of rootstocks and from 35 to 40 coarse, "ropy," tough roots, the latter penetrating the soil to a depth of about 20 inches. The stem is very stout and has an abundance of short-petioled or sessile, acute and broad leaves; the panicle is elongated, drooping, and provided with a profusion of green flowers (Plate XXXVII).

False hellebore flourishes best in a comparatively wet soil. It grows densely in marshy basins, along creek banks, and in swales of nearly all kinds in the upland ranges of the Hudsonian zone. It wilts notably, in most cases beyond recovery, when the soil water content is reduced to from 11 to 14.5 per cent. The flower stalks rarely put in their appearance until about August 5, and in certain places the flowers do not unfold until September 1. The lower flowers expand first, and the lower part of the panicle is the first to mature the seed. Dissemination takes place shortly after maturity, and since the seeds are flat, broad, and winged, they are well scattered. The earliest seeds to ripen in 1909 (about August 25) showed an average germination of 24 per cent. Those which matured after September 5 had practically no viability.

The forage value of false hellebore varies with the time of year, though in a way opposite from that of most grazing plants. Except very early in the spring, prior to the expansion of the leaves, when the young shoots are grazed by sheep to a certain extent, it is seldom eaten until after one or two rather severe frosts. Usually not until after August 15 is any considerable portion of the plant grazed with much relish on upland ranges, but later in the fall sheep eat it. In many instances only 3 or 4 inches of the coarse stalk is left. The leaves and pithy portion of the stalk are the parts relished.

Stockmen generally hold that this plant is poisonous if eaten before it has been frosted. To what extent false hellebore has a toxic effect on stock early in the season is not known, but no authentic cases are on record where sheep have been poisoned by it. The short rootstocks are no doubt poisonous, but late in the season, at the time when the plant is generally grazed, the roots are rarely pulled up.

FIRE WILLOW.

(*Salix scouleriana*.)

In the region studied the willow family, including poplars or aspens, furnish more first-class browse than any other group. Fire willow, or Nuttall's willow as it is sometimes called, is a common invader of burned-over lands, where it is the most important species.



WILD BUCKWHEAT (*POLYGONUM PHYTOLACCAEFOLIUM*).

F-39Q



GERANIUM (GERANIUM VISCOSISSIMUM).

F-400

A portion of the coarse root is shown on the left.

Fire willow rarely develops into tree form in the region studied, though elsewhere it often attains a height of from 15 to 25 feet and a diameter of 8 inches. The leaves are of a light shade beneath, smooth, and free from hairs on the upper surface. The midrib is prominent and yellow (Plate XXXVIII).

This willow grows along mountain streams, in canyons, and on gentle slopes in damp leaf litter or rather poorly disintegrated soils. While it is sometimes sparsely scattered it more often grows in dense clumps. On burned-over areas in canyons and on gentle slopes where the soil has not been rendered sterile, it often produces dense low thickets. On the Wallowa National Forest where it grows in close association with snow bush or buck brush (*Ceanothus velutinus*) in the Canadian zone, it forms what is known as chaparral. In the Hudsonian zone it occurs more sparingly.

Male and female flowers are borne on different bushes, the seed production, of course, being confined to the female ones. The seeds ripen in the spring about the time the leaves have reached full development. The little pods open up soon after maturity and liberate the silky hairy seeds, which are widely distributed.

No tests were made of the viability of the seed of this species. It produces an abundance of seed, but reproduction is mainly vegetative.

In the Wallowa Mountains fire willow is the preeminent browsing plant. The low and spreading habit of growth adds greatly to its value as a sheep forage, and the time at which the leaves are developed renders it valuable as an early browsing plant. As high as sheep can reach, the branches are stripped of their leaves, though the bark is seldom eaten. Since this plant makes a comparatively rapid growth, a portion of the branches are soon beyond the reach of sheep and injury from severe grazing is unusual. In fact, the more sheep browse on the willow the denser becomes the growth. This is due to the vigorous and persistent sprouting of new branches as a result of the trimming back of the young shoots through grazing. Even when a bush is cut to the ground a number of young shoots are produced.

WILD BUCKWHEAT.

(*Polygonum phytolaccaefolium*.)

This plant belongs to the well-known buckwheat family; the genus is represented by some 70 species in the United States.

Wild buckwheat is a perennial with a coarse, fleshy, sparsely branched but deep root. It attains a height of about 2 feet; the stem is well supplied with comparatively large, oval-shaped leaves, and panicles of rather small greenish white flowers (Plate XXXIX).

The species is mainly confined to exposed situations in the Hudsonian zone, though it occurs to a limited extent in both of the bordering zones. It attains its best development on mountain

slopes in a soil with the average amount of moisture.¹ While it seldom grows pure, it is common enough in mixture with grasses of various kinds to give character to the range.

Flower stalks appear from about the latter part of the second week in July until August 5. Matured seeds are found as early as August 1, while the major part of the crop is matured by about August 25. Though the seed crop is ripened early the vitality is not high. The average germination obtained in 1908 and 1909 was 3 and 13.5 per cent, respectively.

Since wild buckwheat inhabits comparatively dry situations, it resumes growth early in the spring and by July 15 has produced an abundance of leafy herbage which is greedily eaten by sheep. After about the last 10 days in August, when the leaves begin to dry up, the plant is no longer relished. In many places where the natural reseedling experiments are being conducted good reproduction of this species has been secured. It withstands trampling remarkably well, and is promising as a plant for the revegetation of depleted ranges under a system of deferred grazing. The nutritive qualities of wild buckwheat are generally considered to be high.

GERANIUM.

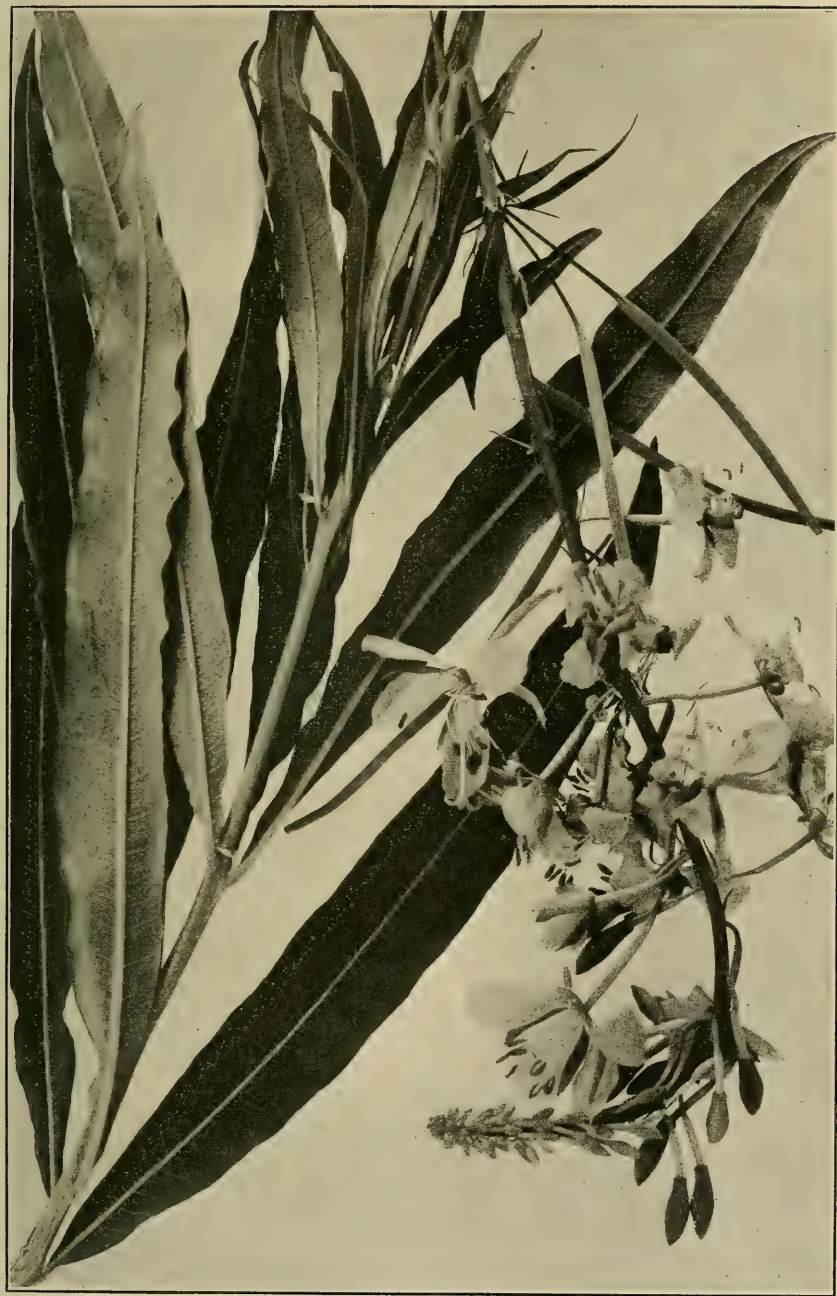
(*Geranium viscosissimum.*)

Geranium belongs to the same family as the well-known alfileria or "filaree," which is so valuable for grazing in certain sections of the country. It is a coarse, much branched, and leafy species (Plate XL), from 1 to 2 feet high. Both the branches and the upper side of the leaves are covered with fine hairs; the leaves are long petioled, large and thick, deeply three-parted; the petals pink or purple, sometimes fading to barely white. The root is very coarse and tough, and rather deep, but not branching.

In the Transition zone this plant is sufficiently abundant to be of considerable value for grazing, and is nearly as common in the Canadian zone, occupying open glades and parks and canyon bottoms and hillsides, in medium moist, preferably gravelly, loam soils rather rich in humus. It rarely grows in dense stand, but in favorable situations is often conspicuous, especially during the flowering period. It is usually associated with Indian paint brush (*Castilleja*) and yarrow (*Achillea*).

The flowering period extends over approximately one month. On the lower ranges it is among the first of the perennial plants to bloom.

¹ In determining the water requirements of this species, it was almost impossible to obtain reliable data by the methods used because of the deep "taproot" which, if only slightly injured, would result in death to the plant within a few hours. An average of all tests attempted showed that it was unable to absorb water at a rate sufficient to reestablish turgidity from the soil in which it grows when the content was reduced to between 8 and 10 per cent. Judging from the species with which it is associated and the habitat in which it grows, these figures appear to be somewhat high.



FIREWEED (*CHAMAENERION ANGUSTIFOLIUM*).

F-41a



WILD CELERY (*LINGUSTICUM OREGANUM*).

F-42Q

In the Canadian zone the flowers begin to unfold about June 20, and by July 20 most of them have expanded. The seed matures from about July 25 to August 15. In 1909 the seed crop from the Canadian zone germinated 29.5 per cent. Reproduction on the range in general is taking place slowly.

Geranium is one of the choice forage plants for cattle and sheep. Since it grows in abundance on the cattle and sheep allotments, it is equally valuable to both classes of stock. When it is young all but the lower portion of the coarse stem is eaten, but later only the flowers, immature fruits, and leaves are grazed. About the time that the seed crop has matured the leaves dry up and the plant loses much of its forage value.

FIREWEED.

(*Chamaenerion angustifolium*.)

Chamaenerion angustifolium is given its name, fireweed, because of its prevalence on burned-over forest lands. This species is the most valuable perennial grazing plant of the evening primrose family. It attains a height of 2 to 5 feet, depending on the situation. The cylindrical stem bears an abundance of long, slender, nearly entire, thin leaves, and the inflorescence consists of a raceme of delicately pink or nearly white, or sometimes purple, flowers developed at the apex of the stem (Plate XLI). The long, slender capsules split into four divisions at maturity, liberating the numerous minute seeds provided with a tuft of long silky hairs, by means of which they are carried great distances by the wind.

In the Wallowa National Forest fireweed is most abundant on burned-over areas in rather dry, often coarse, gravelly and even sterile soils in the Canadian zone. It also occurs in both of the contiguous zones, though never in pure stand. It is one of the first species to invade heavily burned lodgepole-pine forests.

Fireweed is drought resistant, comparing in this respect with some of the grasses which grow both in moist and in dry situations. The plants were found not to wilt excessively until the soil moisture was reduced to between 8.2 and 11.5 per cent, depending upon the particular soil type. In the moister places, where decayed vegetable matter is more abundant, the moisture requirement figures are higher.

The production of flower stalks, like the seed-maturing period, continues for an unusual time. In the warmer situations flowers begin to unfold as early as June 20, and in a few places buds are found at the apex of the raceme as late as the early part of August. The lower flowers are first displayed, and as the season advances there is a gradual sequence or succession in the flowering toward the

apex of the raceme. Accordingly, while the upper part of the raceme is in full flower the lower portion often has well-developed seed pods. In some cases the seed reaches maturity on the lower parts of the raceme while buds are still forming on the upper portion. The seed-maturing period begins about August 1 and continues until inclement weather sets in.

While the viability of the seed is not high, the average for that collected in 1908 and 1909 being 21.5 per cent, the earlier maturing seed runs from 10 to 12 per cent higher than that maturing later. The amount of seed produced is unusually large and reproduction is very abundant.

When young, fireweed is eaten with great avidity. As the season advances, however, the stem become fibrous and unpalatable, and after August 1 only the flowers and leaves are grazed, the stem being left quite naked. Few if any "weeds" are more relished by sheep than fireweed. Horses, too, eat it to a limited extent, and cattle graze it ravenously. Since it begins growth early in the spring and is late in reaching maturity, it furnishes a much relished feed during the greater part of the summer grazing period.

WILD CELERY.

(*Ligusticum oreganum*.)

Ligusticum oreganum, sometimes called wild parsnip, belongs to the same family as cultivated celery, parsnip, and carrot, and in the region studied is called both wild celery and wild parsnip. It has the characteristic parsnip aroma, and resembles the parsnip somewhat in the appearance of the leaf (Plate XLII). It should not be confused with the poisonous water hemlock, which is found in wet soils and is sometimes called "wild parsnip."

Wild celery is a smooth perennial with large aromatic, sparsely branched roots. The leaves are numerous, nearly all basal, and compound, being ternately (in three) then pinnately divided; the umbel is made up of numerous rays with many narrow pointed bracts surrounding the flower cluster.

The plant is distinctly one of the Hudsonian zone. It occurs on all exposures and slopes, but prefers deep, loose, porous and friable, well-drained soils of medium moisture content. Since it does not regenerate by offshoots from running rootstocks, it probably is not capable of forming, even under most favorable conditions, pure or nearly pure stands. It is most commonly associated with mountain bunchgrass, short-awned brome grass, and other species inhabiting the better soils or glades. Its water requirements are higher than those of its associates. The plant wilts usually beyond recovery in a soil whose water content varies from 8 to 9.5 per cent.



SKUNK WEED (*POLEMONIUM PULCHERRIMUM*).

F-43Q

Only a portion of the creeping rootstock is shown.



HIGH HUCKLEBERRY (*VACCINIUM MEMBRANACEUM*).

Showing edible mature berries.

F-440

The leafless flower stalks begin to show about the second week in July, and are nearly all developed during the succeeding four weeks. The seed crop matures, on the average, from about August 15 to September 10, and is disseminated immediately afterward.

The seed has low viability. In 1907 and in the two succeeding seasons a germination of 2, 6, and 11.5 per cent was obtained. The plant, especially the fruiting parts, is very sensitive to frost, which may account in part for the low viability of the seed, since after August 15 frosts are frequent in the situations where it grows. Reproduction is taking place sparingly on the range in general, and even on the allotments that are in process of reseeding under deferred grazing.

Wild celery may be utilized quite as early for grazing purposes as the majority of the grasses, and furnishes ideal feed for sheep from July 20 to August 25. Horses sometimes eat it, though only to a limited extent. Unlike most plants, it is eaten with quite as much relish late in the season as early in the summer. After about August 25 it is not valuable for forage, the leaves being killed by frost, leaving only the naked flower stalk.

SKUNKWEED.

(*Polemonium pulcherrimum*.)

Skunkweed, so called because the plant has an odor somewhat suggestive of a skunk, is a fine hairy plant from 4 to 8 inches in height, with sparingly branched slender stems. The leaves are basal and compound, the oblong leaflets numbering from 7 to 15 or even more. The corolla of the clustered flowers is blue, turning very pale or nearly white before dropping. The root system is exceptionally superficial and spreading (Plate XLIII). The plant grows in tuftlike patches of shoots arising from creeping rootstocks. If a single plant is pulled from the ground in a loose soil most of the lateral roots, as well as the main root, come up with it.

Skunkweed is confined almost exclusively to the Hudsonian zone. While it often produces a conspicuous and luxuriant growth in the open, it prefers the somewhat diffuse light of open forest lands. In exposed situations, where the soil type is relatively coarse in texture, the plant does not succumb from excessive transpiration until the soil-water content is reduced to 7 per cent, and in protected situations, where the soil texture is rather fine, death due to wilting comes when the water content is reduced to 10 per cent.

The flowers begin to open during the second week in July and bloom throughout August, though after the middle of the month most have expanded. About August 20 the seeds begin to ripen, and this continues as long as the season is favorable. The seed crop

is comparatively fertile. In 1908 and 1909 an average germination of 41.5 and 32.5 per cent was obtained.

Since skunkweed grows above the range ordinarily grazed by cattle, it furnishes only sheep forage. It is eaten ordinarily with about the average amount of relish, and at times ravenously. It is best for grazing purposes from about July 20 to the last week in August. At the latter end of the season the foliage is frequently frostbitten and dry.

— HIGH HUCKLEBERRY.

(*Vaccinium membranaceum*.)

High huckleberry is the most valuable grazing species of its family in the region studied. It is a much branched and leafy shrub from 1 to 4 feet tall (Plate XLIV), the twigs slightly angled, leaves thin, not shining, short-petioled. The flowers are inconspicuous and solitary, and the corolla, usually five-toothed, is greenish or purplish in color. The berry, when mature, is purplish black. It is slightly acid and is highly valued as food.

High huckleberry is confined to the Transition and Canadian zones, being most abundant in the latter. It is commonly found under yellow pine, fire willow, and lodgepole pine, and accordingly endures a considerable amount of shade. It is characteristic of strongly acid or sour soils, and is rarely, if ever, found on limestone or even neutral soils.

On the lower elevations the flowers begin to appear about June 1, and by July 1 most of them have expanded. The berry begins to develop dark pigment as early as July 15, and the ripening period continues until about the first week in September, at which time most of the berries are clinging. Since the berries are palatable to both birds and animals, they are almost entirely consumed, and seed distribution is thorough.

Sheep browse this plant with avidity, and it is grazed from about June 15 to late in the autumn, though it is most palatable early in the season.

Throughout the Canadian and Hudsonian zones and up to the limits of tree growth another species, known as red huckleberry (*Vaccinium scoparium*), occurs in even greater abundance than the high huckleberry. As a forage plant, however, it does not compare with the latter, though it is grazed to a limited extent. This species also is confined to acid soils.

HORSEMINT.

(*Agastache urticifolia*.)

Horsemint is the most widely distributed representative of the mint family in the Wallowa Mountains, and is of the highest value for grazing.



HORSEMINT (*AGASTACHE URTICIFOLIA*).

F-489



BLUE BEARDTONGUE (*PENTSTEMON PRO CERUS*).

A portion of the running rootstocks is shown.

F-460

It is an erect smooth perennial plant from 1 to 3 feet tall, with square stems and opposite, petioled leaves, the margins coarsely and irregularly toothed. The flowers are clustered in a dense terminal spike, the corolla pink-white or sometimes light purple. The root is coarse, fibrous, woody, and rather spreading (Plate XLV).

Horsemint is widely distributed. It is met with occasionally in the Transition zone, and is abundant in the Canadian and Hudsonian zones. Though occurring but sparingly in the upper altitudes of the latter zone, it is of considerable value for forage up to 8,000 feet. The best development and densest stands are found in loose soils of medium moisture on the glades in the upper Canadian and lower Hudsonian. While it often predominates over associated species in the better and moister soils, it almost always grows in scattered stands, especially in shallow, coarse, gravelly clays.

The flowers begin to form about July 10, but all are not expanded as a rule until August 20. Fertilization is largely effected through insects, mainly bees. The two-lipped corollas drop soon after fertilization.

Matured seeds are usually found by the last week in August though the entire crop is rarely ripened until about September 10. The matured, brownish-black, plump, hard-coated, oval seed-like nutlets are not disseminated at once, but are readily expelled when the seed cluster is vigorously shaken, shooting out some distance from the parent plant. For a high-range plant the germination power of the seed is about the average. In 1908 and 1909 representative samples gave an average of 16 and 28.5 per cent, respectively. Where this species is given a chance to reproduce, i. e., on ranges where the seed crop is allowed to mature prior to grazing, reproduction is taking place, though sparingly. The actual amount of seed produced per plant is relatively small, and since only about one-fourth is fertile the species is succeeding as well as might be expected.

Horsemint begins growth early in the season and matures late and consequently is relished by stock at all times during the summer. Both sheep and cattle eat it with much relish, though sheep graze it with greater avidity. Horses eat it only to a limited extent, and it can not be considered of value for this class of stock. Until the flowering parts begin to drop the entire cluster is consumed, so that early in the season the whole plant is eaten. After about August 10 only the leaves are grazed. Since younger leaves remain green some little time after seed maturity, horsemint is preferred in the fall of the year to some of the more valuable grasses and forage plants.

BLUE BEARDTONGUE.

(*Pentstemon procerus*.)

About 100 species of *Pentstemon* are found in the United States and Mexico, many of them of value for grazing. Blue beardtongue

is the most highly relished as well as the most abundant of the various species on the high range lands of the Wallowa National Forest.

Blue beardtongue is a perennial with conspicuous lateral running rootstocks which send out a number of shoots reaching a height of 4 to 12 inches. The whole plant is smooth and somewhat shiny; the lower leaves are long petioled, smaller than those arising from the middle of the stem; the upper leaves are small and without leaf stalks (Plate XLVI). The flowers, usually 5 in a cluster, are arranged in whorls. The bright blue corolla is lipped, the lower lip bearded within. As in all beardtongues, one of the five stamens is sterile, and in this species it is distinctly bearded also.

This plant is conspicuous in the Hudsonian zone, though it grows in varying abundance at lower altitudes. Open parks and medium moist meadows of deep, loose, but well-drained soils are the favorite habitats. In moisture requirement it resembles wild celery (*Ligusticum oreganum*), with which it is commonly associated. In the characteristic soil type in which blue beardtongue grows, wilting beyond recovery does not occur until the soil-water content is reduced to from 10 to as low as 8 per cent.

The flowers begin to open about July 10, and all are out by August 15. About the time the last flowers expand the first matured seeds are found, though, of course, on different plants. The seed tested in 1909 showed a viability of 18.5 per cent. In previous years no germination studies were made. Under favorable conditions on protected ranges, however, reproduction is excellent, and it is apparent that this plant will increase in abundance under the deferred-grazing system.

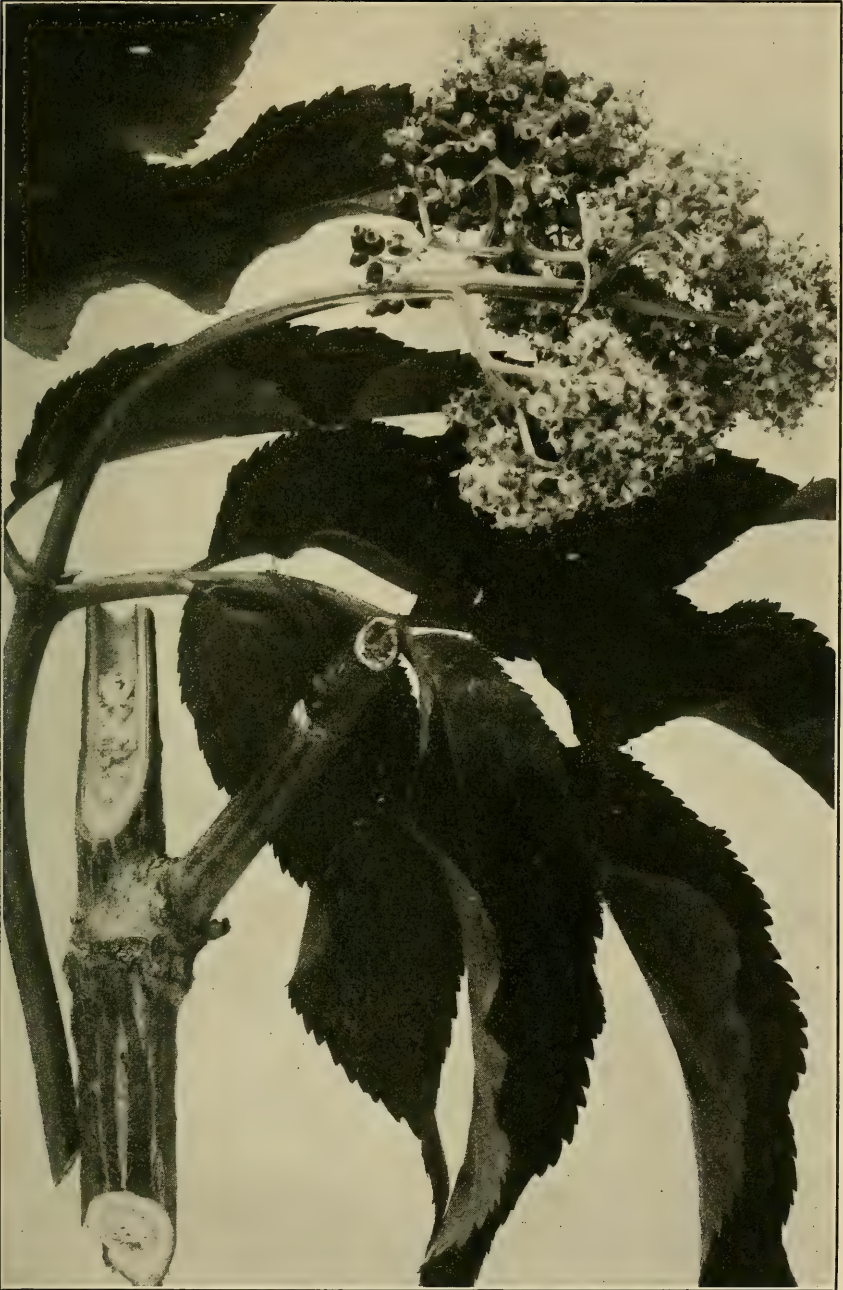
Blue beardtongue seems to be eaten by sheep with more eagerness than any of its allied species. Since its growth begins promptly in the spring, it furnishes a fair portion of the valuable early forage. The leaves, but not the stems, are eaten even after the seeds have matured, though they are not as palatable as earlier in the summer. The plant is of highest value for grazing between about July 15 and August 20.

Besides the blue beardtongue three species of *Pentstemon*, *P. deustus*, *P. fruticosus*, and *P. venustus*, all grazed at certain times in the season, are common in the Wallowa Mountains.

MOUNTAIN ELDER.

(*Sambucus melanocarpa*.)

Mountain elder is a shrub with stems 3 to 6 feet high rising in profusion from a common crown; twigs of one year old growth smooth, shiny green-brown and slightly angled, the pith yellow-brown; bark of the older branches rather thick, rough, dark yellow-



MOUNTAIN ELDER (*SAMBUCUS MELANOCARPA*).

F-47Q

Observe the smooth bark of the young twig in contrast to the coarse bark of the older branch.



MOUNTAIN ELDER (*SAMBUCUS MELANOCARPA*).

F-480

Because of the palatability of mountain elder, sheep usually leave the lower branches quite bare of foliage.

Dead clumps of mountain elder are often found on the range. Since the species is comparatively short lived this condition may be due, in part at least, to age.

brown; leaflets 5 to 9, smooth or slightly hairy, light green on the lower side. As shown in Plate XLVII, the flower clusters are convex, as broad as high, the flowers white, fruit shiny black, without bloom. In the lower elevations this species is associated with blue elder (*S. glauca*), which is readily distinguished by the white pith in the year-old stems, the treelike form of the older plants, the flat-topped flower clusters and the chalky bloom on the black berries which gives them a bluish appearance—thus the name blue elder.

Mountain elder is most abundant on hillsides, in the bottom of mountain canyons, in ravines, and along brooks and mountain streams in fertile, friable, gravelly soils of varying degrees of moisture. It occurs in the Transition and Hudsonian zones, but is more abundant in the Canadian, often in association with ninebark (*Opulaster pauciflorus*), western larch, Douglas fir, and open stands of lodgepole pine. It prefers open situations, though partial shade does not prevent luxuriant growth.

The attractive white-flower clusters begin to show about July 15 on the higher ranges, and earlier on the lower ones. About September 1 most of the berries have reached full development. These are eaten by birds and a few mammals, a wide dissemination of the seeds being thus insured. No germination tests were made of this species, but observations on the range show that it is reproducing well.

As a browse it is as valuable, though not nearly so abundant, as willow. In localities where the two are associated elder is browsed first. Because of its low branching habits and the unusual relish with which it is browsed there is danger of mountain elder being eaten too closely. A common example of such a condition is shown in Plate XLVIII.

Mountain elder is also highly relished by sheep and is grazed with relish at times by cattle. It occurs mainly in the Transition zone, but never in great abundance, and therefore is not highly important as a browsing plant.

VALERIAN.

(*Valeriana sitchensis*.)

Valerian is one of the most characteristic plants on old burns in the Hudsonian and upper Canadian zones where the soil has not been rendered sterile and the moisture conditions are about average. It is a perennial and attains a height of from 1 to 2 feet; the stem is slender with usually three pairs of pinnately compound leaves, the lower long-petioled (Plate XLIX). The flower cluster is dense and contracted, the corolla tubular and pinkish white; from the woody,

horizontal, creeping rootstocks long fibrous roots are developed. The rootstock is peculiarly aromatic.

Valerian prefers a rather porous, somewhat gravelly, and comparatively deep fertile soil, but does not require a large amount of moisture, as it made average development in such soil where the minimum water content was only 9 per cent. Destructive wilting came, however, when the water content was reduced to between 7 and 8.5 per cent.

The plant begins to flower profusely about July 15, and by August 15 nearly all the flowers have expanded. The seed crop matures from August 20 to the close of the season, some individual plants never reaching maturity. The early-maturing seed in 1908 and 1909 germinated 21.5 and 26 per cent, respectively. On protected ranges reproduction is taking place sparingly.

Both cattle and sheep are very fond of valerian at nearly any time during the summer, but it grows in greatest abundance on the sheep ranges. On burns covered with dead and down timber sheep search for it and graze it quite as readily as the fireweed, with which it is commonly associated. Early in the season the flowers, leaves, and lower portion of the stem are consumed; later in the summer only the flowers and leaves are eaten.

MOUNTAIN DANDELION.

(*Agoseris glauca*.)

Mountain dandelion, so called because of its abundance on the upland ranges and similarity in appearance to the ordinary dandelion, is a milky-juiced perennial from 4 to 8 inches high. In loose soils it has a sparsely branched taproot, which penetrates to a depth of 1 to 2 feet, but in rocky soils the root is usually branched. The oblong basal leaves, generally tapering to the apex, are smooth and somewhat shiny, while the flower stalk, about a third longer than the leaves, is covered sparsely with coarse hair (Plate L). The solitary head of yellow flowers is borne at the summit of a naked stalk; the mature seeds bear a crown of copious, slender, simple, white, bristle-like hairs.

While this species occurs to a limited extent on the lower ranges, it is much more abundant on the grazing lands in the Hudsonian zone. On open plateaus and well-drained glades of loose, gravelly, deep, clay loam it grows most luxuriantly. It is fairly drought resistant, not wilting excessively in the finely disintegrated soil in which it naturally occurs until the soil-water content is reduced to from 8 to 10 per cent. In favorable situations the stand is comparatively heavy, but ordinarily it is rather scattered.

The flower stalks begin to appear in the latter part of July, and by August 15 nearly all are in evidence. This is somewhat later than the



VALERIAN (*VALERIANA SITCHENSIS*).

F-489



MOUNTAIN DANDELION (*AGOSERIS GLAUCA*).

Showing expanded flower and matured fruit not yet disseminated.

F-500

average. The seed crop, too, is produced late. A few matured seed heads are seen about August 10, but most of the seed reaches maturity in September, often in the latter part of the month. Fortunately this plant is very resistant to frost, and consequently the seed continues to develop after many other species, such as wild celery, have been killed.

The vitality of the seed crop, taking into account that produced both early and late in the Hudsonian zone, gave an average of 29, 38, and 41 per cent, respectively, in the three years of test. Mountain dandelion is reproducing comparatively well on the range, and promises to respond favorably to any system of protection which will allow the seed crop to mature.

Sheep seek the plant in preference to many grasses and weedy species. Each season it is eaten down to the ground, leaving only the coarse base. In the early part of the summer, and even until the seeds are nearly mature, the young, tender, juicy flower stalks, leaves, and even the flowers, are eaten with avidity. Few other species enjoy as long a growing season. In 1909 the leaves were still green and highly palatable to sheep on October 1. The seeds are usually not disseminated for a considerable time after maturity, but the hairy appendages which are the means of affecting their dispersal by the wind are not objectionable to stock.

WOOLLY WEED.

(*Hieracium cynoglossoides.*)

To see this peculiarly woolly plant, sometimes referred to as woolly hieracium, one would hardly think of it as valuable for forage. Sheepmen state, however, that the only objection is that it does not occur more abundantly.

It is from 1 to 2 feet in height with numerous leaves arising from the crown of the perennial, coarse and much-branched root, and an abundance of leaves on the stem. The dense covering of fine soft hairs on the stem and leaves gives it a very distinctive character (Plate LI).

It is unusual to find a dense ground covering of woolly weed. It grows almost invariably with other weedy perennials, such as mountain dandelion, blue beardtongue, and numerous grass species, among which it seldom predominates. In soil and moisture requirements it is almost identical with mountain dandelion. Individual plants wilted beyond recovery in soil varying in water content from 8 to 10.5 per cent. These figures are similar to those obtained in the case of certain bunch grasses with which woolly weed is associated.

The flower stalks are produced between July 15 and August 20, the greatest number being sent up after August 1. The seeds begin

to ripen about August 25, but owing to the late date of the flower-stalk production only a small seed crop is matured. In 1908 and 1909 only 9.3 and 12.5 per cent, respectively, of the seed showed fertility. From these figures and from observations on the range, it does not seem likely that a marked increase in the species can be effected by range protection and improved methods of handling.

If palatability and not abundance and distribution were taken into account, woolly weed would rank among the most important range plants. It is so closely grazed early in the summer that nothing but the root remains. The coarse and comparatively deep root system protects it from actual killing and under ordinary conservative handling of stock it may at least be expected to hold its own.

CONEFLOWER.

(*Rudbeckia occidentalis*.)

Of the several valuable nongrasslike forage plants, coneflower, sometimes called "nigger head," is one whose actual grazing qualities are often underrated. It is a conspicuous plant, attaining a height of 2 to 5 feet, and having numerous marginally toothed, somewhat rough, ovate leaves, those lowest on the stem being petioled, and the upper ones sessile. Numerous shoots are sent out from the coarse, woody, fibrous perennial root, and the older plants have a bunched growth. This plant, as shown in Plate LII, is usually not branched, and the dense, rayless, oblong, brown head of flowers, resembling a cone, is borne at the apex of the stem.

The most common and favorable habitats of coneflower are the somewhat shaded banks, mountain swales, and hillsides where the soil is moist but not saturated. One of its most common associates is false hellebore, whose moisture requirements are almost identical. Coneflower is occasionally met with on open, well-drained glades, but never in abundance. In such habitats, in the characteristic basaltic clay loam soil of the region, wilting of all leaves did not take place until the soil moisture was reduced, on the average, to 14 per cent. In the richer soils, those which are heavily impregnated with organic matter, pronounced and long periods of wilting, usually followed by death of the plant, were recorded when the soil contained from 16 to 18.5 per cent water content.

Early in the season the "button" or flower head begins to develop and by August 15 has virtually attained full growth. The seeds, however, do not begin to ripen until about the last week in August the ripening period extending well into September, and the seeds remaining in the head until late in the autumn. The germinative strength of the seed crop in the three years of test was 16, 24.5, and 11, respectively. Even in the most favorable situations the seedlings stand is rather sparse, but reproduction from roots is abundant.



WOOLLY WEED (*HIERACIUM CYNOGLOSSOIDES*).

F-619



CONEFLOWER (*RUDBECKIA OCCIDENTALIS*).

F-52Q

Coneflower furnishes a large supply of forage. The stems are rather tough even when young, and only the flower heads and leaves are eaten. As the plant attains its full height the seed heads are generally above the reach of sheep. While in some localities the stems are quite bare after the lands have been grazed, this is rather the exception. In mixture with other palatable plants it is grazed with relish, but when it furnishes the bulk of the feed, stock are apt to scatter widely in search of more desirable forage.

YARROW.

(*Achillea lanulosa*.)

Yarrow is one of the most widely distributed plants in the region studied. It is found from the lower Transition to the upper Hudsonian zone, on intermediate ranges in such abundance as to be of considerable grazing value throughout the mountains.

Wild tansy, as yarrow is sometimes called because of its resemblance and close relationship to the tansy cultivated in gardens, is a perennial with stems densely woolly, 12 to 24 inches high, terminating in conspicuous flower clusters, convex in shape, and with white ray flowers. The silky leaves, finely divided or dissected (Plate LIII), are produced in abundance, as are also the leaves which originate from the horizontal rootstocks.

This species while succeeding best in a comparatively light, well-drained clay loam, does well in a variety of soils and situations. It inhabits glades and open parks, however, where it gets the benefit of full sunlight. In the lower situations it is scattered, and it does not anywhere form a pure stand. On the upland ranges, however, it usually forms great bunches or tussocks, as shown in Plate LIV. It is comparatively drought resistant. Individual plants tested did not wilt to a point causing death until the moisture content was reduced to 12.3 in one case and 10 per cent in another.

The flowering period is unusually prolonged. On the lower ranges the flower heads begin to show early in June, but in the Hudsonian zone not until about July 20. In the mountain lands flowers which were just beginning to open have been observed as late as September 15. As a result, a large percentage of the seed crop in the high range never reaches maturity. The earliest fully ripened seeds are found about August 20. In 1908 and 1909 the germination tests averaged 16.5 and 39.2 per cent, respectively. Over 90 per cent of the seed crop of 1909 from the lower ranges was fertile. On protected range areas reproduction is very promising.

Both cattle and sheep seek out yarrow from among its associated species and eat it with avidity. As a rule the unpalatable stems are

deprived of their attractive flower heads and leaves early in the season. Sheep prefer the plant to many abundant grasses, even during the period when the latter are most palatable.

BUTTERWEED.

(*Senecio triangularis*.)

Senecio triangularis is not only the largest and most abundant of the butterweeds in the region studied, but also the most palatable. It grows from 2 to 5 feet tall, and has a leafy stem which terminates in dense clusters of 20 or 30 bright yellow flowers. The leaves are all petioled and toothed. Shoots are sent up in abundance from the lateral running rootstocks (Plate LV).

Butterweed is closely confined to the higher ranges, being abundant in the upper Canadian zone and throughout the Hudsonian zone. It is distinctly a marsh plant and is closely restricted to situations with wet or saturated soils. On creek banks, in the vicinity of springs, and in swales of various kinds, it is often the chief plant. It was found to wilt beyond recovery in a soil whose moisture content varied from 11.5 to 14 per cent.

Usually the flowers do not begin to appear until about the last week in July, and the blooming period continues until the last week in August. The seed crop begins to reach maturity when the late flowers are unfolding. The ripening period continues until inclement weather, the latest flowers failing to mature seeds. The seed which had ripened by September 5 germinated, in 1908 and 1909, 18 and 26 per cent, respectively. The later maturing seed has a notably lower viability.

Early in the year butterweed is eaten with such avidity that almost nothing is left. Until August 1 the lower part of the stem is the only portion not consumed. As the season advances, however, only the flower clusters, the upper rapidly growing terminal part of the stem, and the leaves are grazed. Among late forage plants, butterweed is one of the most highly relished. Since it is found only in moist situations, however, its amount is limited.

Another butterweed much relished by sheep is *S. columbianus*, often called small butterweed. In the Wallowa National Forest this species occurs in scattered stand on well-drained soils throughout the Canadian and Hudsonian zones. It begins growth early and is of value for grazing only in the spring. Sheep prefer it to grasses, and eat it with such ravenousness that it has little opportunity to reseed under the usual grazing practice. Its relatively small size (Plate LVI), different habitats, and earlier flowering period, easily distinguish it from *Senecio triangularis*.





CHARACTERISTIC BUNCHED GROWTH OF YARROW ON UPLAND RANGES.

SUMMARY.

ECOLOGICAL REQUIREMENTS.

The figures given in Table 2 represent the relative water requirements of the different important forage plants studied.¹ Owing to the importance of having the plants advanced to as nearly the same point of development as possible when the drought tests were made aerial conditions were slightly different. The error due to this fact, however, is very largely offset by the duplication of the tests in the case of virtually all species.

It is a well-established fact that the amount of moisture remaining in the soil when the plant wilts beyond recovery is determined by the physical structure of the substratum. The object in making the wilting coefficient determinations, then, is principally to show (1) that certain species occupy quite different soil types, and (2) that the soil types (textures) are widely contrasted as shown by the notable difference in the wilting coefficients for the various species. For example, mountain bunch grass (*Festuca viridula*) does not wilt seriously in the soil in which it characteristically grows until the water content is reduced to between 7 and 9.5 per cent. This plant is adapted to coarser and less rich soils than is mountain onion (*Allium validum*), for example, which is confined to exceptionally black, mealy soils, and which wilts beyond recovery when the soil moisture content drops to between 14 and 16 per cent. Owing to the relatively small amount of moist soil found in mountain range lands, it is evident that a species like mountain onion would not occur nearly as abundantly as mountain bunch grass.

As a means of comparing habitat requirements, the species are grouped in three classes as follows:

Class A, plants of high moisture requirement—those inhabiting saturated soils, such as open marshes, wet meadows and bogs; class B, plants of medium moisture requirement—those inhabiting relatively heavy soils which are saturated during the early part of the season, but later contain a medium amount of moisture; and class C, plants of low moisture requirement—those occurring in well-drained lands, open glades, and exposed situations.

It will be observed that practically three-fourths of the most valuable forage species are dry-land plants. This fact is of high economic importance, since the major portion of the range lands are well drained and afford conditions favorable only to plants which are comparatively drought resistant.

It is noted that a few species fall under more than one head so far as concerns their habitat requirements—that is, they are not strictly

¹ A resumé of the potent climatic factors under which these tests were conducted was published in the Journal of Agricultural Research, Vol. III, No. 2, 1914, "Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation," pp. 95-102.

confined to any one soil type. Such plants, however, do not afford nearly the amount of forage those do which are found generally in the more open habitat (usually referred to as drought-resistant plants), where the soil is not finely disintegrated, is less well supplied with organic material, and has a wilting coefficient notably lower.

A relatively small proportion of the range lands are wet throughout the growing season; while bogs, marshes, and the like almost invariably support a more luxuriant stand of vegetation than any other, the herbage usually lacks in two essentials—palatability and nutritiousness. Those who have observed stock as to their choice of forage have noticed that sheep avoid marshes and wet habitats to a marked degree; that cattle drift to the better drained lands for most of their feed; and horses, if unaccustomed to marsh vegetation, such, for example, as sedges and rushes, graze it eagerly for a couple of days, after which they will not remain on the succulent feed if any other is available. Campers and mountain workers have found that their pack and saddle animals can not do the work when feeding on marsh and bog vegetation that they can on drier feed. Also, stockmen have found that fat made on succulent feeds is not of a solid character and in the case of long drives to market or of shipment shrinkage is abnormally heavy.

LIFE HISTORY.

To aid the reader in comparing the different phases of growth, the time of seed maturity, and the viability of the seed crop produced by the various forage species discussed, the results are summarized in Table 3.

It will be seen that the time of the flowering period varies more widely than that of seed maturity. This is due primarily to the greater contrast between the moisture and temperature of the soil during spring than in late summer and autumn seasons. Growth, of course, starts more promptly and vigorously in the better drained and consequently warmer soils than in the moister and cooler situations. Owing to the more uniform physical conditions in a given life zone as the season advances, the seed maturing period is much more uniform and is completed in less time than that of flower-stalk production. All species and situations considered, the flower stalks are mainly produced between July 5 and August 10, and the seed matured between August 15 and September 1. While the time of flower-stalk production and period of seed maturity are influenced by the physical factors, even greater contrast is brought about by weakening of the vegetation due to overgrazing. Plants seriously weakened through abusive grazing are late in producing flower stalks and in maturing the seed. In extreme cases no flower stalks are produced, and, in general, such seed as is produced has little or no germinative power. Plants less seriously weakened pro-



BUTTERWEED (*SENECIO TRIANGULARIS*).



SMALL BUTTERWEED (*SENECIO COLUMBIANUS*).

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duce a small amount of viable seed, while those which have not been injured send up their flower stalks early, mature the seed crop before killing frosts occur in the autumn, and produce fertile seed.

The data compiled relative to the life-history performances of the different forage species have made possible the adoption of what is known as the "deferred or rotation grazing system." This system provides for the deferment of grazing on an allotment until the seed crop has matured—the size of the area to be protected depending, of course, upon the time at which the bulk of the seed crop ripens. Subsequent to complete revegetation, the area is grazed relatively early, thereby providing for the protection of a similar area elsewhere on the allotment without in any way jeopardizing the grazing interests or by wasting any part of the annual forage crop during the time required for revegetation. When the entire allotment has been thoroughly restocked, each portion, subdivision or camp is restricted from grazing but once in every three or four years, thus allowing the plants to maintain a maximum vigor and to provide an occasional seed crop, which is essential to the maintenance of a permanent stand.

The details essential to revegetation by means of deferred and rotation grazing have been given in previous publications.

TABLE 2.—Soil moisture requirements of native forage plants.

Name of plant.		Soil-water content at time of excessive wilting.	Class.
Local.	Scientific.		
		<i>Per cent.</i>	
High huckleberry.....	<i>Vaccinium membranaceum</i>		A.
Mountain onion.....	<i>Allium validum</i>	14.0-16.0	
Slender reed-grass.....	<i>Cinna latifolia</i>	13.5-16.0	
Tall meadow-grass.....	<i>Panicularia nervata</i>	12.0-14.5	
Tall swamp sedge.....	<i>Carex exsiccata</i>	22.5-24.0	
Black hair-grass.....	<i>Deschampsia atropurpurea</i>	12.5-14.7	B.
False hellebore.....	<i>Veratrum viride</i>	11.0-14.5	
Fireweed.....	<i>Chamaenerion angustifolium</i>	8.2-11.5	
Fire willow.....	<i>Salix scouleriana</i>		
Porcupine grass.....	<i>Stipa occidentalis</i>	9.5-11.5	
Rush.....	<i>Juncus mertensianus</i>		B.
Rush.....	<i>Juncus orthophyllus</i>		
Small wild onion.....	<i>Allium fibrillum</i>		
Smooth wild rye.....	<i>Elymus glaucus</i>	7.5- 9.8	
Tufted hair-grass.....	<i>Deschampsia caespitosa</i>	11.5-14.5	
Wild celery.....	<i>Ligusticum oreganum</i>	8.0- 9.5	A and B.
Wild onion.....	<i>Allium platyphyllum</i>		
Wood rush.....	<i>Juncoides parviflorum</i>	10.0-12.5	
Butterweed.....	<i>Senecio triangularis</i>	11.5-14.0	
Coneflower.....	<i>Rudbeckia occidentalis</i>	16.0-18.5	
Marsh pine grass.....	<i>Calamagrostis canadensis</i>	11.0-14.0	C.
Mountain timothy.....	<i>Phleum alpinum</i>	14.0	
Sheep sedge.....	<i>Carex illota</i>	14.0	
Big bunch grass.....	<i>Agropyron spicatum</i>	5.5- 7.5	
Blue bunch grass.....	<i>Festuca idahoensis</i>		
Elk grass.....	<i>Carex geyeri</i>	6.5	C.
Geranium.....	<i>Geranium viscosissimum</i>		
Horsemint.....	<i>Agastache urticifolia</i>		
Little bluegrass.....	<i>Poa sandbergii</i>	6.5- 7.3	
Little needle grass.....	<i>Stipa minor</i>	9.2-11.5	
Mountain bunch grass.....	<i>Festuca viridula</i>	9.5- 7.0	C.
Mountain dandelion.....	<i>Agoseris glauca</i>	8.0-10.0	
Mountain June grass.....	<i>Koeleria cristata</i>	10.0-13.5	
Mountain wheat grass.....	<i>Agropyron violaceum</i>	6.0- 7.5	
Onion grass.....	<i>Melica bella</i>	6.3- 8.5	
Pine grass.....	<i>Calamagrostis suksdorfii</i>	5.5- 8.5	B and C.
Red bunch grass.....	<i>Agropyron flexuosum</i>		
Rush.....	<i>Juncus confusus</i>		
Rush.....	<i>Juncus parryi</i>	5.5- 7.0	
Soft cheat.....	<i>Bromus hordeaceus</i>	5.5	
Spiked trisetum.....	<i>Trisetum spicatum</i>	7.5- 9.5	B and C.
Short-awned brome grass.....	<i>Bromus marginatus</i>	5.5- 8.0	
Tall bluegrass.....	<i>Poa brachyglossa</i>		
White foxtail.....	<i>Sitanion velutinum</i>	6.0- 8.5	
Woolly weed.....	<i>Hieracium cynoglossoides</i>	8.0-10.5	
Yarrow.....	<i>Achillea lanulosa</i>	10.0-12.3	B and C.
Alpine redtop.....	<i>Agrostis rossae</i>	7.0- 8.5	
Blue beardtongue.....	<i>Penstemon procerus</i>	8.0-10.0	
Skunk weed.....	<i>Polemonium pulcherrimum</i>	7.0-10.0	
Slender hair-grass.....	<i>Deschampsia elongata</i>	8.5-15.0	
Wild buckwheat.....	<i>Polygonum phytolaccaefolium</i>	8.0-10.0	B and C.
Valerian.....	<i>Valeriana stichensis</i>	7.0- 8.5	

TABLE 3.—Time of flower-stalk production, time of seed maturity, and seed viability of the native forage plants.

Local.	Name of plant.	Scientific.	Flower stalks produced.			Seeds matured.			Germination of seed.
			1907	1908	1909	1907	1908	1909	
Mountain bunch grass	<i>Festuca viridula</i>		July 5-Aug. 20.	July 10-Aug. 25	July 3-Aug. 15.	Aug. 18-Sept. 5.	Aug. 15-Sept. 5.	Aug. 5-Sept. 5.	Per cent. 12.2
Blue bunch grass	<i>Festuca idahoensis</i>		June 10-July 25	July 5-July 15	June 30-Aug. 1.	Aug. 15-Aug. 30.	Aug. 10.....	July 20-Aug. 30.	11.0-21.0
Partridge grass	<i>Stipa idahoensis</i>		July 25-Aug. 10.	July 20-Aug. 10.	June 15-Aug. 10.	Aug. 15-Aug. 30.	Aug. 10.....	Aug. 15-Aug. 30.	27.0
Little needle grass	<i>Stipa minor</i>		July 25-Aug. 10.	July 20-Aug. 15.	do.....	Aug. 20-Aug. 31.	Aug. 20-Sept. 10.	Aug. 10-Sept. 10.	58.2-76.0
Mountain timothy	<i>Phleum alpinum</i>		July 15-Aug. 25	July 15-Aug. 15.	July 12-Aug. 1.	Aug. 15.....	Aug. 20-Sept. 15.	Aug. 15-Sept. 10.	79.0-86.8
Slender reed grass	<i>Chloris latifolia</i>		July 5-Aug. 15	July 10-Aug. 15.	July 25-Aug. 15.	Aug. 25-Sept. 10.	Sept. 1-Sept. 20.	Aug. 20-Sept. 30.	29.0-41.0
Alpine reedtop	<i>Agrostis rosea</i>		July 5-Aug. 15	July 10-Aug. 5.	July 25-Aug. 15.	Aug. 25-Sept. 5.	Aug. 20-Sept. 15.	Aug. 25-Sept. 30.	69.5
Marsh pine grass	<i>Calamagrostis canadensis</i>		July 20-Sept. 10.	Aug. 1-Sept. 20.	July 20-Aug. 30.	Aug. 15.....	Aug. 10-Sept. 10.	Aug. 10-Sept. 15.	59.5-86.5
Curled pine grass	<i>Calamagrostis canadensis</i>		June 25 to Aug. 20.	Aug. 25 to Aug. 20.	do.....	Sept. 1-Sept. 10.	Sept. 15-Sept. 20.	Aug. 25-Sept. 10.	20.0-30.0
Slender hair grass	<i>Deschampsia cespitosa</i>		July 25-Aug. 10.	July 25-Aug. 15.	July 15-Aug. 10.	Sept. 1-Sept. 10.	Sept. 1-Sept. 10.	Aug. 25-Sept. 10.	41.5-56.5
Black hair grass	<i>Deschampsia cespitosa</i>		July 15-Aug. 1.	July 20-Aug. 31.	July 15-Aug. 25.	Sept. 5-Sept. 10.	Aug. 15-Sept. 10.	Aug. 25-Sept. 10.	19.5
Spiked trisetum	<i>Deschampsia cespitosa</i>		July 15-Aug. 1.	July 10-Aug. 25.	July 15-Aug. 25.	Aug. 20-Sept. 10.	Aug. 20-Sept. 15.	Aug. 25-Sept. 10.	14.0-16.0
Mountain June grass	<i>Trisetum spicatum</i>		July 10-July 25	July 10-Aug. 15.	July 5-Aug. 15.	Aug. 25.....	Aug. 20-Sept. 10.	Aug. 15-Sept. 5.	4.0
Onion grass	<i>Koeleria cristata</i>		July 20-Aug. 10.	July 15-Aug. 15.	July 10-Aug. 10.	Aug. 10-Sept. 1.	July 15-Aug. 20.	July 20-Aug. 20.	7.0-38.4
Mountain onion grass	<i>Melica spectabilis</i>		July 10-Aug. 1.	July 10-Aug. 15.	July 5-Aug. 15.	Aug. 10-Sept. 1.	Aug. 15-Aug. 20.	Aug. 15-Sept. 25.	38.0-55.0
Little bluegrass	<i>Poa brachygloua</i>		June 1-July 1	June 1-July 10.	June 1-Aug. 5.	Aug. 5-Aug. 20.	Aug. 1-Aug. 20.	Aug. 15-Sept. 10.	63.0
Tall bluegrass	<i>Poa brachygloua</i>		July 25-Aug. 10.	July 25-Aug. 10.	July 10-Aug. 10.	Aug. 15-Sept. 10.	Aug. 15-Sept. 15.	Aug. 20-Sept. 10.	26.2
Short-awned bromegrass	<i>Bromus marginatus</i>		July 15-Aug. 1.	By July 15, average.	July 10-Aug. 10.	Not recorded.	Aug. 10-Sept. 10.	Aug. 20-Sept. 10.	83.5
Soft cheat	<i>Bromus hordeaceus</i>		July 15-Aug. 1.	July 10-Aug. 1.	July 10-Aug. 1.	Sept. 1.....	Aug. 20-Sept. 10.	Aug. 20-Sept. 10.	21.2
Tall meadow grass	<i>Panicum virgatum</i>		Aug. 1-Aug. 20.	Aug. 10-Sept. 1.	July 25-Sept. 1.	Sept. 1.....	Aug. 20-Sept. 10.	Aug. 20-Sept. 10.	43.0-82.5
Big bunch grass	<i>Agropyron spicatum</i>		do.....	Aug. 5-Aug. 20.	July 25-Aug. 15.	(1)	Aug. 20-Sept. 10.	Aug. 20-Sept. 10.	15.2
Mountain wheat grass	<i>Agropyron violaceum</i>		do.....	Aug. 10-Aug. 31.	July 25-Aug. 15.	Aug. 15-Aug. 30.	Aug. 20-Sept. 10.	Aug. 20-Sept. 10.	27.5
Red bunch grass	<i>Agropyron flexuosum</i>		July 5-Aug. 1.	July 5-Aug. 5.	July 1-Aug. 5.	Aug. 15-Aug. 30.	Aug. 1-Aug. 20.	Aug. 5-Sept. 30.	6.0-32.0
Smooth wild rye	<i>Elymus glaucus</i>		June 25-Aug. 1.	June 20-Aug. 5.	June 20-Aug. 1.	Aug. 20.....	Aug. 20-Sept. 15.	Aug. 15-Sept. 10.	21.2
White foxtail	<i>Stachyon velutinum</i>		June 20-July 15	June 20-July 10.	June 20-July 20.	Aug. 25-Sept. 5.	Sept. 1-Sept. 15.	Aug. 20-Sept. 15.	43.0
Tall swamp sedge	<i>Carex ciliata</i>		July.....	June 20-July 10.	June 20-July 20.	Aug. 25-Sept. 5.	Sept. 1-Sept. 15.	Aug. 20-Sept. 15.	27.5
Sheep sedge	<i>Carex ciliata</i>		July.....	June 20-July 10.	June 20-July 20.	Aug. 25-Sept. 5.	Sept. 1-Sept. 15.	Aug. 20-Sept. 15.	6.0-32.0
Flk grass	<i>Juncus gerardi</i>		June 20-July 15.	June 20-July 10.	June 20-July 20.	Aug. 1-Aug. 15.	July 15-Aug. 5.	Aug. 1-Aug. 20.	7.5
Rush	<i>Juncus gerardi</i>		July 10-Aug. 5.	July 10-Aug. 10.	July 5-Aug. 5.	Aug. 25-Sept. 10.	Aug. 25-Sept. 5.	Aug. 25-Sept. 10.	37.0
Wood rush	<i>Juncus tenuiflorus</i>		July 25-Aug. 10.	July 25-Aug. 15.	July 20-Aug. 15.	Aug. 17-Sept. 1.	Aug. 15-Aug. 30.	Aug. 10-Aug. 30.	7.5
Mountain onion	<i>Allium validum</i>		July 1-Aug. 5.	July 5-Aug. 15.	July 5-Aug. 15.	Aug. 25.....	Aug. 25-Sept. 10.	Aug. 20-Sept. 5.	37.0
Small wild onion	<i>Allium fibrillum</i>		June 1-June 25	June 1-June 25.	June 1-July 5.	Aug. 1-Aug. 10.	July 10-July 30.	July 15-Aug. 10.	21.5-26.0
Wild onion	<i>Allium platyphllum</i>		do.....	June 5-July 1.	June 5-July 15.	do.....	do.....	do.....	3.0-13.5
False hellebore	<i>Veratrum viride</i>		Aug. 5-Sept. 1.	Aug. 5-Aug. 31.	July 25-Sept. 1.	Sept. 1.....	Sept. 1.....	Aug. 25-Sept. 15.	
Fire willow	<i>Salix scouleriana</i>		June 1-June 20.	June 5-June 15.	June 1-June 15.	(1)	Aug. 1-Aug. 25.	July 25-Aug. 15.	
Wild buckwheat	<i>Polygonum phytolaccaefolium</i>		July 20-Aug. 5.	July 15-July 31.	July 15-July 30.	(1)	Aug. 1-Aug. 25.	July 25-Aug. 15.	

¹ Practically no seeds reached full maturity.

² A blank following the date of seed maturity indicates that only a few seeds matured at the time specified, and the remainder of the seed crop never reached full development.

TABLE 3.—Time of flower-stalk production, time of seed maturity, and seed viability of the native forage plants—Continued.

Name of plant.		Flower stalks produced.			Seeds matured.			Germination of seed.
Local.	Scientific.	1907	1908	1909	1907	1908	1909	
Geranium.....	<i>Geranium viscosissimum</i>	Not recorded....	June 25-July 25.....	June 20-July 25.....	Not recorded....	July 30-Aug. 15.....	July 25-Aug. 15.....	Per cent. 29.5
Fireweed.....	<i>Chamaenerion angustifolium</i>	do.....	June 20-Aug. 1.....	June 25-Aug. 10.....	do.....	Aug. 1-Sept. 15.....	Aug. 10-Sept. 15.....	16.5-28.0
Wild celery.....	<i>Lithosium oreanum</i>	July 20-Aug. 5.....	July 12-Aug. 5.....	July 10-Aug. 10.....	Aug. 25.....	Aug. 20-Sept. 10.....	Aug. 15-Sept. 1.....	2.0-11.5
Stinkweed.....	<i>Poligonum buckherianum</i>	Not recorded....	July 10-Aug. 20.....	July 12-Aug. 15.....	Not recorded....	Aug. 20-Sept. 10.....	Aug. 15-Sept. 5.....	32.5-41.5
High lupine.....	<i>Vaccinium membranaceum</i>	June 5-June 25.....	June 10-July 1.....	June 5-July 10.....	Aug. 1-Sept. 10.....	Aug. 5-Sept. 5.....	Aug. 5-Sept. 15.....	16.0-28.5
High lupine.....	<i>Amorpha arborescens</i>	July 10-Aug. 20.....	July 8-Aug. 20.....	July 15-Aug. 15.....	Aug. 25.....	Sept. 1-Sept. 15.....	Aug. 15-Aug. 5.....	18.5
Blue bellflower.....	<i>Pentstemon procerus</i>	Not recorded....	July 10-Aug. 15.....	July 10-Aug. 5.....	Not recorded....	Aug. 10-Sept. 1.....	Aug. 15-Aug. 30.....	21.5-25.0
Mountain elder.....	<i>Sambucus racemosa</i>	do.....	July 10-Aug. 5.....	July 15-Aug. 10.....	do.....	Aug. 20-Sept. 10.....	Aug. 25-Sept. 15.....	20.0-11.0
Mountain elder.....	<i>Valeriana sitchensis</i>	July 15-Aug. 15.....	July 8-Aug. 10.....	July 5-Aug. 20.....	Aug. 20.....	Aug. 10-Aug. 25.....	Aug. 10-Sept. 5.....	9.3-12.5
Mountain dandelion.....	<i>Anemone patens</i>	July 20-Aug. 15.....	Aug. 10-Sept. 5.....	July 25-Aug. 20.....	Aug. 10.....	Aug. 25-Sept. 15.....	Aug. 25-Sept. 15.....	11.0-21.5
Woody weed.....	<i>Hieracium ciliatoloboides</i>	Not recorded....	July 15-Aug. 20.....	July 20-Aug. 15.....	Not recorded....	Aug. 25-Sept. 20.....	Aug. 20-Sept. 5.....	16.5-50.0
Coneflower.....	<i>Rudbeckia acutifolia</i>	July 10-Aug. 15.....	July 10-Aug. 20.....	July 15-Aug. 20.....	Aug. 25.....	Aug. 20.....	Aug. 20.....	18.0-26.0
Yarrow.....	<i>Achillea lanulosa</i>	June 10-Aug. 25.....	June 10-Aug. 10.....	June 10-Sept. 15.....	Sept. 1-Sept. 10.....	Aug. 20.....	Aug. 20-Aug. 30.....	
Butterweed.....	<i>Senecio triangularis</i>	Aug. 1-Aug. 25.....	Aug. 1-Aug. 25.....	June 20-Aug. 20.....	Sept. 1-Sept. 10.....	Aug. 25.....		

APPENDIX: PLAN OF STUDY.

In obtaining information on the individual forage species, consideration was given as far as possible to the following points:

1. Name of plant, both Latin and common.
2. Distribution.
 - a. Characteristic zone.
 - b. Most typical habitat; abundance and density of stand.
3. Usual plant associations and communities.
4. Habit of growth.
 - a. Annual or perennial.
 - b. Tufted growth, height growth, and character of herbage.
5. Character of root system.
 - a. Spreading fibrous root, or taproot with lateral rhizomes.
 - b. Depth of roots in soil.
6. Ecological requirements.
 - a. Soil and moisture preferences.
 - b. Drought resistance.
7. How flower stalks are sent up.
8. How fertilized.
9. When seeds are matured.
10. How and when seeds are disseminated.
11. Seed habits, strong or weak. Viability tests.
12. Period of germination.
13. Classes of stock which graze it.
14. Suitability for early or late grazing.
15. Palatability when green and when matured.
16. Time at which it is usually grazed.
17. Relative forage value.

Information on the points in the above outline was secured through investigation extending over four successive years. The actual ecological requirements of the various species could be determined only through physical-factor measurements.

An important factor affecting the distribution, and more particularly the succession of vegetation, is available soil moisture. Experiments showed that the greatest physiological activity is manifested at the time fertilization is taking place or immediately after the completion of the flower-stalk production but prior to a pronounced development of the seed.

The comparative ability of the various species to withstand drought was determined by ascertaining for each species the amount of moisture remaining in the soil when the plant had wilted to a point from which it could not recover. Unless pronounced wilting was actually in progress as a result of aerial and soil conditions, it was necessary to bring it about by cutting off the water supply from the plant. In making determinations in the field one of the methods used was as follows: The plants to be tested were dug up, with the roots undisturbed in their own soil, particular care being taken to prune off as little of the root system as possible. The block of soil

held together by the intertwining of the roots was wrapped in burlap for purposes of transfer and immediately placed upon suitably cut wire screen (see Plate I), which, when fitted and fastened together around the soil body in the form of a basket, was placed in the hole created by the digging of the plant. In this manner the plant was not subjected to too rapid drying and its normal functions were unimpaired. After the plant had fully recovered from any slight disturbance due to digging, it was elevated slightly in order to increase the rapidity of the drying process. The wire-basket method made the plant portable, a very desirable feature in field work since the plant could easily be removed from the field during showers and when in a wilted condition prior to soil sampling and placed under shelter—in this case in a carefully-placed 14-ounce canvas tent—and thus protected from direct effects of wind and sun when the specimen might recover its turgor if not wilted excessively.

The other method of ascertaining the water requirements was to dig away the soil on all sides of the plant, leaving in place the central core of soil supporting the roots, the size of which would depend upon the spreading habit of the root system (see Plate I, fig. 2). This method was used especially for certain species with deeply penetrating taproots, such as wild celery (*Ligusticum oreganum*) and wild buckwheat (*Polygonum phytolaccaefolium*). These, it was found, would not respond normally to the wire-basket method of treatment. The drying process brought about in this way, owing to the fact that the water supply was not wholly cut off from below, was slightly more gradual than in the case of the wire-basket method, but the results of the tests for species which did not have a distinct taproot, such as grasses, proved to be virtually the same as those secured for the same species by the wire-basket method. When the plant reached a condition of pronounced wilting and turgor could not be recovered, two representative soil samples were taken, weighed immediately to avoid possible discrepancy due to evaporation, placed in a soil-drying oven and subjected to a temperature not exceeding 212° F. for several hours until they were dry, then reweighed. The difference between the dry weight of the samples and the weight when taken at the time the plant was in a wilted condition represents the amount of moisture remaining in the soil at a time when the root hairs were unable, under the conditions, to absorb moisture rapidly enough to maintain the form of the plant and finally to recover its turgidity. The depth and location at which soil samples were taken were regulated by the depth of penetration and position of the roots. This operation was followed by protecting the specimen from the direct effect of sun and wind by placing a small tent shelter over it. In all cases the soil moisture figures given are based upon specimens which failed to recover their turgor, unless otherwise stated. All moisture require-

ment determinations of species were made from two to four weeks after the flower stalks began to show.

Since the character of the soil and the nature of the habitat play an important rôle in the amount of water the substratum may yield to the plant, the wilting of species was tested as nearly simultaneously and under as nearly the same topographic features as possible. The results therefore are comparable.

To ascertain the germination per cent of the seed crop, matured seeds were collected in the fall of each year for three years from typical situations, and germination tests were made in the seed-testing laboratory of the United States Department of Agriculture.



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EFFECT OF FALL IRRIGATION ON CROP YIELDS AT BELLE FOURCHE, S. DAK.

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INTRODUCTION.

One of the conspicuous features of the climate of the Great Plains area is the light precipitation received during the winter months. Throughout most of the Plains region, about three-fourths of the annual precipitation occurs during the six months from April to September, inclusive,¹ so that the winter months are, comparatively, very dry. As a result, it is commonly found that after producing a crop the land remains dry from harvest time until the rainy season of the following year. The soil on such land during this period may be deficient in moisture not only near the surface but throughout the zone of action of the roots of crop plants. It has been assumed that this soil-moisture deficiency might have an unfavorable influence on the growth of crops, both by hindering the germination of spring-sown seed and by retarding or preventing the desired movement of the water received as precipitation or applied in irrigation during the growing season.

The practice of fall irrigation—the application of water to the land in the fall of the year—has been advocated as a corrective of this condition in irrigated regions. Various writers on irrigation have suggested the desirability of fall irrigation, and a few investi-

¹ Briggs, L. J., and Belz, J. O. Dry farming in relation to rainfall and evaporation. U. S. Dept. Agr., Bur. Plant Indus. Bul. 188, 17 p., 23 fig., 1 pl. 1910.

gators have made field studies of the subject. Knorr,¹ experimenting for three years on the North Platte Reclamation Project in western Nebraska with wheat, oats, barley, potatoes, sugar beets, and corn, found that the fall irrigation of the land on which these crops were to be grown increased the yield an average of 16 per cent. The yield increases secured in these experiments were ascribed to the fact that fall irrigation resulted in more moisture in the surface soil at seeding time in the spring and also in a better absorption of moisture by the soil to a depth of 6 feet during summer irrigation. These experiments were conducted on a sandy loam soil at the Scottsbluff Experiment Farm, a field station of the Bureau of Plant Industry.

The favorable results secured at Scottsbluff suggested the advisability of repeating the experiments at another point in the Great Plains area where the soil conditions are different from those at Scottsbluff. Accordingly, in the autumn of 1913 a series of fall-irrigation experiments involving oats, sugar beets, flax, potatoes, barley, corn, and wheat was inaugurated at the Belle Fourche Experiment Farm on the Belle Fourche Reclamation Project in western South Dakota. The experiments with these seven spring-planted crops were continued through 1914, 1915, and 1916. The results secured are reported in this bulletin.²

RAINFALL.

During the nine years, 1908 to 1916, inclusive, the annual rainfall at the Belle Fourche Experiment Farm ranged from 6.64 inches, in 1911, to 21.02 inches, in 1915, the mean for the 9-year period being 14.05 inches. In connection with the problem of fall irrigation it is important to consider the distribution of the rainfall with reference to the fall period—the period between the beginning of harvest and the time of fall irrigation—and to the winter period. The mean rainfall of these periods during the nine years of record and the actual rainfall during the time in which the fall-irrigation experiments were conducted are shown in Table I.

TABLE I.—*Precipitation at the Belle Fourche Experiment Farm, 1908 to 1916, inclusive.*

Period covered.	Mean, nine years, 1908 to 1916.	Period of experiment.			
		1913	1914	1915	1916
Total annual.....	14.05	12.53	11.70	21.02	13.95
Fall period (August to October, inclusive).....	3.75	4.50	3.24	2.95	.....
Winter period (November to March, inclusive).....	2.15	1.84	2.52	1.99	

¹ Knorr, Fritz. Experiments with crops under fall irrigation at the Scottsbluff Reclamation Project Experiment Farm. U. S. Dept. Agr. Bul. 133, 17 p., 5 fig. 1914.

² The writers desire to acknowledge their indebtedness to Mr. O. R. Mathews, Assistant, Dry-Land Agriculture Investigations, for assistance in the conduct of these experiments.

The table shows the light precipitation which occurs during the winter months, from November to March, inclusive. During two of the three winters included in the period of experiment there was somewhat less than the mean winter rainfall for the period of record, 2.15 inches, and during the other there was slightly more than the mean. Likewise, two of the three fall periods affecting the experiments were drier and one was wetter than the mean for this fall period, 3.75 inches. From this it would appear that if fall irrigation were desirable at Belle Fourche, its benefits would have been emphasized during the period of these experiments.

SOIL.

The soil on which these experiments were conducted is an extremely heavy clay of the class popularly known as "gumbo." Soils of this general character cover wide areas in the northern Great Plains. This particular soil has been classified by the Bureau of Soils as Pierre clay, of which the average mechanical composition is reported¹ as follows:

	Percent.
Fine gravel.....	0.2
Coarse sand.....	1.1
Medium sand.....	1.4
Fine sand.....	5.5
Very fine sand.....	13.0
Silt.....	43.2
Clay.....	35.0

According to the same authority, the Pierre clay covers about one-third of the area of the Belle Fourche Reclamation Project and occurs on this area to a uniform depth of about 6 feet. It has been formed through the weathering of the underlying beds of Pierre shale. According to a report² of a reconnaissance soil survey made by the Bureau of Soils, the Pierre clay covers an area of nearly eight million acres in the western half of South Dakota.

Important characteristics of this soil are its great water-carrying capacity, its high water retentivity, and the extreme changes of volume which accompany changes in its moisture content. Mathews³ found that this soil will carry about 30 per cent of water and that about half of this is available to crops. The latter do not begin to suffer from lack of water unless the soil moisture content approaches 17 per cent, which is approximately the wilting coefficient of this soil. The importance in fall irrigation of the extreme changes of volume accompanying changes in moisture content of this soil will be discussed later.

¹ Strahorn, A. T., and Mann, C. W. Soil survey of the Belle Fourche area, South Dakota. *In* U. S. Dept. Agr., Bur. Soils, Field Oper. 1907 [9th Rpt.], p. 898. 1909.

² Coffey, G. N., and others. Reconnaissance soil survey of western South Dakota. *In* U. S. Dept. Agr., Bur. Soils, Field Oper. 1909 [11th Rpt.], p. 1401-1476, illus., pl. 9-15. 1912.

³ Mathews, O. R. Water penetration in the gumbo soils of the Belle Fourche Reclamation Project. U. S. Dept. Agr. Bul. 447, 12 p., 4 fig. 1916.

METHODS USED IN THE EXPERIMENTS.

The experiments were conducted in field P, Series I, II, III, and IV, seven tenth-acre plats being used in each series. A diagram of these plats is shown in figure 1. The land was first broken in August, 1911, and it produced oats in 1912 and again in 1913. It is uniform in topography and soil. The crops of 1912 and 1913 were harvested from the field as a whole, no record having been secured of the production of the different series of plats. Series II and IV were irrigated on November 11, 1913, November 11, 1914, and November 10, 1915. Except for this fall irrigation, the treat-

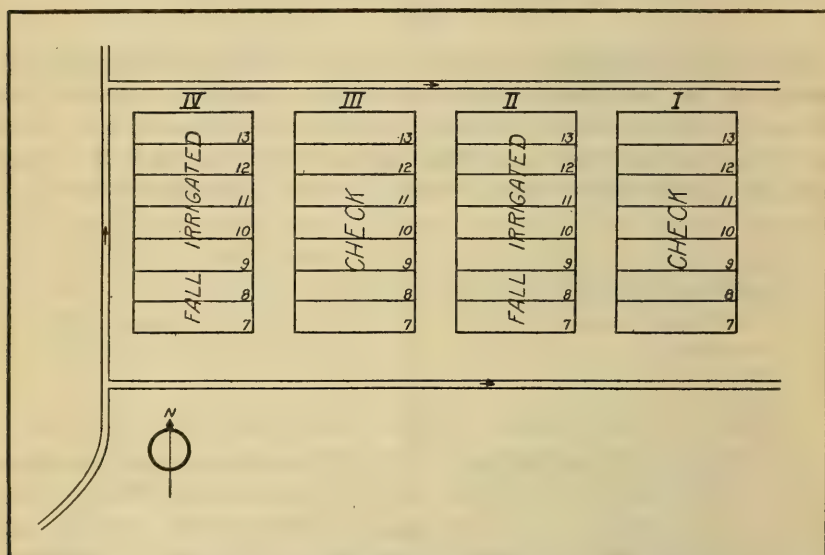


FIG. 1.—Diagram of a part of field P, Belle Fourche Experiment Farm, showing the location of the plats used in the fall-irrigation experiments. The arrows indicate the direction of the flow of the water in the irrigation laterals supplying these plats.

ments applied to Series II and IV were uniform with those applied to Series I and III.

The fall irrigation was applied each year after the plats were plowed, except that in the autumn of 1914 the plats which that year had produced intertilled crops were not plowed. Low earth dikes were thrown up at the lower side of the plats to impound the water sufficiently to insure a complete covering of the land. The water was then applied by flooding and allowed to run on each plat from three to four hours. The summer irrigation of each crop was uniform on all four series as to both time and method of application. No attempt was made to measure the water applied, but the methods of irrigation recognized in the locality as good-farming methods were followed. The sugar beets and potatoes were irrigated by the furrow method and the other crops by field flooding.

The experiments were conducted in duplicate each year, the seven plats in Series I duplicating those in Series III, while the plats in Series II and IV were duplicates. The following crop varieties were used: Oats, Great Dane in 1914 and Swedish Select in 1915 and 1916; sugar beets, South Dakota No. 40 in 1914 and Kleinwanzleben in 1915 and 1916; flax, Minnesota No. 25; potatoes, Eureka in 1914 and 1915 and U. S. No. 4452 in 1916; barley, Minnesota No. 6 in 1914, Himalaya (Guy Mayle) in 1915, and Chevalier in 1916; corn, Payne White Dent in 1914 and 1916 and Martens White Dent in 1915; and wheat, Defiance in 1914, Pringle Champlain in 1915, and Marquis in 1916. The positions occupied by the crops on each of the four series each year, the crop sequence on each plat during the 3-year period, and the number of summer irrigations applied are shown in Table II.

TABLE II.—Sequence of crops and number of irrigations applied to each in the fall-irrigation experiments at the Belle Fourche Experiment Farm in 1914, 1915, and 1916.

Plat.	1914		1915		1916	
	Crop.	Number of irrigations.	Crop.	Number of irrigations.	Crop.	Number of irrigations.
No. 7.....	Oats.....	3	Beets.....	1	Oats.....	1
No. 8.....	Beets.....	3	Flax.....	2	Potatoes.....	1
No. 9.....	Flax.....	2	Potatoes.....	1	Beets.....	2
No. 10.....	Potatoes.....	4	Barley.....	1	Wheat.....	1
No. 11.....	Barley.....	2	Corn.....	1	Barley.....	1
No. 12.....	Corn.....	3	Wheat.....	2	Corn.....	1
No. 13.....	Wheat.....	2	Oats.....	2	Flax.....	1

As shown in Table II, an intertilled crop followed a close-planted crop on each plat except No. 13 in 1915 and 1916 and No. 10 in 1916. More irrigation was necessary in 1914 than in either 1915 or 1916, as the growing season of 1914 received somewhat less rainfall than either of the others. The variations in both crop sequence and summer irrigation were the same on all four series.

All cultural operations on the four series were uniform as to both character and time of performance throughout the period of experiment. These included the ordinary operations incident to the production of the seven field crops involved. The land was manured from October 6 to 10, 1915, when 12 tons per acre of well-rotted barnyard manure were applied uniformly to all the plats.

RESULTS OF THE EXPERIMENTS.

In the conduct of these experiments attention was directed chiefly to the crop yields secured on fall-irrigated land as compared with those of land not so irrigated and to the soil-moisture conditions on the two groups of plats, particularly before the first summer irrigation each season. It was to be expected that any important

differences in the yields of the crops on the several plats would be associable with soil-moisture differences in the spring, as the only variation in the treatment of the land was the irrigation applied to half the plats in the fall of each year.

CROP YIELDS.

Two plats of each of the seven crops were grown each year on the fall-irrigated land, and the same number were grown on check series, the latter receiving no fall irrigation. The yields are reported in detail in Table III.

TABLE III.—*Yields of crops in the fall-irrigation experiments at the Belle Fourche Experiment Farm in 1914, 1915, and 1916.*

Plats and year.	Series.	Wheat.	Oats.	Barley.	Flax.	Corn.	Beets.	Potatoes.
		<i>Bushels.</i>	<i>Bushels.</i>	<i>Bushels.</i>	<i>Bushels.</i>	<i>Bushels.</i>	<i>Tons.</i>	<i>Bushels.</i>
Fall-irrigated plats:								
1914.....	II	31.5	47.8	29.1	17.0	53.4	8.9	172
	IV	28.5	39.0	26.8	10.5	45.8	7.3	127
1915.....	II	24.0	70.9	35.7	18.8	29.3	5.1	108
	IV	19.3	60.6	34.8	16.3	29.0	3.6	77
1916.....	II	15.5	80.6	39.2	10.4	50.4	13.2	267
	IV	13.8	72.2	38.3	9.1	45.4	12.2	254
Average, three years.....		22.1	61.9	33.9	13.7	42.2	8.4	167
Check plats:								
1914.....	I	24.6	40.0	28.7	17.4	47.2	9.5	173
	III	19.3	47.8	26.0	14.8	51.4	7.1	158
1915.....	I	22.7	80.0	43.2	16.3	29.3	5.9	105
	III	24.5	80.3	33.5	19.1	33.7	5.7	100
1916.....	I	14.3	73.9	41.8	12.1	47.9	13.5	225
	III	15.3	84.7	43.6	11.8	53.9	13.9	272
Average, three years.....		20.1	67.8	36.1	15.2	43.9	9.2	172

In order to facilitate comparisons of the yields shown in Table III, the figures have been calculated in percentages, and the relative yields are shown in Table IV, in which the yields of the check plats are represented as 100 per cent. The yield shown for each crop is the average of duplicate plats.

TABLE IV.—*Relative yields (expressed in percentages) of crops in the fall-irrigation experiments at the Belle Fourche Experiment Farm in 1914, 1915, and 1916.*

Crop.	1914			1915			1916			3-year average.		
	Fall irrigated.	Check.	Gain or loss by fall irrigation.	Fall irrigated.	Check.	Loss by fall irrigation.	Fall irrigated.	Check.	Gain or loss by fall irrigation.	Fall irrigated.	Check.	Gain or loss by fall irrigation.
Wheat.....	137	100	+37	92	100	-8	98	100	-2	110	100	+10
Oats.....	99	100	-1	82	100	-18	96	100	-4	91	100	-9
Barley.....	102	100	+2	92	100	-8	91	100	-9	94	100	-6
Flax.....	85	100	-15	99	100	-1	88	100	-12	90	100	-10
Corn.....	101	100	+1	94	100	-6	94	100	-6	96	100	-4
Beets.....	98	100	-2	74	100	-26	93	100	-7	91	100	-9
Potatoes.....	90	100	-10	90	100	-10	105	100	+5	97	100	-3
All crops.....	102	100	+2	89	100	-11	95	100	-5	96	100	-4

The figures in Table IV show that in 1914 the yields of wheat, barley, and corn were higher on the fall-irrigated plats than on the check plats, the increases being 37, 2, and 1 per cent, respectively, while the yields of the four other crops were lower on the fall-irrigated land, and that the average yield increase of the seven crops in that year was 2 per cent in favor of fall irrigation. In 1915 the yields of all the crops were lower on the fall-irrigated land, the average decrease being 11 per cent. In 1916 all the crops yielded less on the fall-irrigated plats than on the checks, except potatoes, which yielded 5 per cent more. In the 3-year average, wheat on fall-irrigated land showed an increase of 10 per cent, while all the other crops showed decreases ranging from 3 to 10 per cent, the average yield decrease of the seven crops on fall-irrigated land for the 3-year period being 4 per cent of the average yield of the check plats.

The fact that of the 42 duplicate plat averages secured in the 3-year period only four were in favor of fall irrigation would support a presumption that fall irrigation on this soil was detrimental. However, since not all the yields were against fall irrigation, it is possible that the yield variations were accidental. In order to determine whether these differences were significant, the probable errors of the average yields have been calculated. The results are shown in Table V, in which the yields secured during the 3-year period are summarized.

TABLE V.—*Summary of the yields secured in the fall-irrigation experiments at the Belle Fourche Experiment Farm in 1914, 1915, and 1916, showing the probable errors of the averages.*

Crop.	Unit of yield.	Fall-irrigated plats.		Check plats.		Difference in favor of fall irrigation.
		Number of plats averaged.	Average yield per acre.	Number of plats averaged.	Average yield per acre.	
Wheat.....	Bushels...	6	22.1± 2.2	6	20.1± 1.4	+2.0± 2.6
Oats.....	do.....	6	61.9± 5.0	6	67.8± 6.0	-5.9± 7.8
Barley.....	do.....	6	33.9± 1.5	6	36.1± 2.5	-2.2± 2.9
Flax.....	do.....	6	13.7± 1.4	6	15.2± .9	-1.5± 1.7
Corn.....	do.....	6	42.2± 3.3	6	43.9± 3.1	-1.7± 4.5
Beets.....	Tons.....	6	8.4± 1.1	6	9.2± 1.1	-.8± 1.5
Potatoes.....	Bushels...	6	167 ±23.0	6	172 ±19.0	-5.0±30.0

The figures in the last column in Table V show for each of the seven crops the difference between the average yield of the fall-irrigated plats and that of the check plats during the 3-year period. None of the differences was as great as the probable error, so that all must be regarded as insignificant. A similar tabulation of the yields of straw and stover (which are not shown here) produces a like result, there being no significant differences in the average yields of these products.

The explanation of the somewhat lower average yields secured on the fall-irrigated land lies in the relatively low productivity of Series

IV, one of the two fall-irrigated series. The 3-year average yield of the crops on Series IV was 16 per cent lower than the corresponding average of Series II, while the 3-year averages of the two check series, I and III, were identical. The relatively low productivity of Series IV may have been associated with a heavy infestation of gumbo weed (*Iva axillaris*). This weed was more abundant on Series IV than on any of the other series throughout the period of experiment. At any rate, there is nothing in the data to indicate that fall irrigation influenced the crop yields.

SOIL MOISTURE.

When the experiments were planned, it was the intention to make soil-moisture determinations shortly after the fall irrigation each year and also during the early part of the growing season. It was found, however, that because of cold weather the soil remained wet so long after the fall irrigation that fall sampling was impracticable. All the soil-moisture data available, therefore, were secured during the spring and early summer of each of the three years of the period of the experiment. In each sampling two cores were taken on each plat and composited to a single sample for each foot section.

Soil moisture in 1914.—Three samplings were made in 1914, on May 5, June 18, and June 27. The samples secured on May 5 were taken from the plats seeded to oats, barley, and wheat, two plats of each crop on the fall-irrigated land and the same number of check plats, a total of six plats representing each fall treatment. These samples were taken 34 days before the first irrigation. The second set of samples, taken June 18, was from the same plats as the May 5 samples and from the two flax plats, a total of eight plats representing each fall treatment. This sampling was done 10 days after the first irrigation of the oats, wheat, and barley and one day after the flax was irrigated. The samples secured on June 27 were from the same plats as those taken on June 18, and no irrigation water was applied between the two sampling dates. These moisture determinations were made to a depth of 4 feet. A summary of the results is given in Table VI, which also shows the probable errors of the averages of moisture content.

Table VI shows that on May 5 the average moisture content of the upper 3 feet of soil on the fall-irrigated plats was higher than that of the corresponding depths on the check plats, the greatest difference being in the second foot, where it amounted to 8.3 ± 0.5 per cent. The soil of all the plats, however, contained an abundance of moisture, the moisture content being well above the wilting coefficient, which is approximately 17 per cent. The difference in the moisture content of the fourth foot on the same date, 2.2 ± 1.2 per cent, was insignificant. On June 18, after the plats had been irrigated, the only significant differences were found in the second and third feet, where the soil of the fall-irrigated plats contained about 5 per cent more

moisture than that of the check plats. On June 27 there were no significant differences in moisture content, all differences being less than their probable errors. It will be noted that the moisture content of the fourth foot was practically the same on each of the three sampling dates. The results of the moisture determinations made in 1914 showed that while the soil of the fall-irrigated plats contained more moisture than that of the check plats early in the season, when all the plats had abundant moisture, the differences decreased as the season advanced and disappeared before the end of June.

TABLE VI.—*Summary of the results of soil-moisture determinations made in 1914 in the fall-irrigation experiments at the Belle Fourche Experiment Farm.*

Date.	Depth.	Fall-irrigated plats.		Check plats.		Difference in favor of fall irrigation.
		Number of plats averaged.	Moisture content.	Number of plats averaged.	Moisture content.	
	<i>Feet.</i>		<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
May 5.....	1	6	28.7±0.4	6	25.1±0.6	+3.6±0.7
Do.....	2	6	28.8±.4	6	20.5±.3	+8.3±.5
Do.....	3	6	26.6±.3	6	21.0±.3	+5.6±.4
Do.....	4	6	21.7±1.0	6	19.5±.7	+2.2±1.2
June 18.....	1	8	23.1±.6	8	21.5±.7	+1.6±.9
Do.....	2	8	25.3±.7	8	20.3±.9	+5.0±1.1
Do.....	3	8	26.5±.6	8	20.9±.5	+5.6±.8
Do.....	4	8	21.5±.8	8	20.2±.9	+1.3±1.2
June 27.....	1	8	22.3±.6	8	22.1±.7	+.2±.9
Do.....	2	8	25.8±.4	8	25.0±.7	+.8±.3
Do.....	3	8	26.4±.6	8	26.3±.9	+.1±1.1
Do.....	4	8	20.8±.8	8	20.7±.9	+.1±1.2

Soil moisture in 1915.—The sampling in 1915 was done on May 24 and June 10. All the plats in Series I and II were sampled on the first date and those in Series III and IV on the second. No irrigation water was applied to any of the plats in 1915 until July 14, so that the moisture determinations were made five and seven weeks, respectively, before the first irrigation. The samples were taken to a depth of 3 feet. Table VII gives a summary of the results of the moisture determinations, together with the probable errors of the averages of moisture content.

TABLE VII.—*Summary of the results of soil-moisture determinations made in 1915 in the fall-irrigation experiments at the Belle Fourche Experiment Farm.*

Date.	Depth.	Fall-irrigated plats.		Check plats.		Difference in favor of fall irrigation.
		Number of plats averaged.	Moisture content.	Number of plats averaged.	Moisture content.	
	<i>Feet.</i>		<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
May 24.....	1	7	29.2±0.3	7	30.4±0.2	-1.2±0.3
Do.....	2	7	29.4±.4	7	29.4±.4	0
Do.....	3	7	28.1±.2	7	26.0±.9	+2.1±.9
June 10.....	1	7	30.0±.3	7	30.3±.6	-.3±.7
Do.....	2	7	29.8±.2	7	29.4±.6	+.4±.6
Do.....	3	7	27.9±.3	7	27.6±.7	+.3±.8

Except for a very slightly lower average moisture content in the first foot of the fall-irrigated plats sampled May 24, the moisture determinations made in 1915 disclosed no differences large enough to be considered significant between the fall-irrigated plats and the checks. As in the spring of 1914, the soil on all the plats sampled contained an abundant supply of moisture. As the moisture content of all the plats before the first irrigation was found to be substantially the same, no further moisture determinations were made during the season.

Soil moisture in 1916.—The first irrigation in 1916 was applied July 6. Soil-moisture determinations were made to a depth of 2 feet on all the plats in oats, wheat, and barley on June 10, and the plats in potatoes, beets, corn, and flax were sampled to the same depth on June 30. The results of the two samplings are summarized in Table VIII, which also shows the probable errors of the averages of moisture content.

TABLE VIII.—*Summary of the results of soil-moisture determinations made in 1916 in the fall-irrigation experiments at the Belle Fourche Experiment Farm.*

Date.	Depth.	Fall-irrigated plats.		Check plats.		Difference in favor of fall irrigation.
		Number of plats averaged.	Moisture content.	Number of plats averaged.	Moisture content.	
	<i>Feet.</i>		<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
June 10.....	1	6	27.7±0.6	6	27.4±1.0	+0.3±1.2
Do.....	2	6	29.2±.8	6	29.2±.9	0 ±1.2
June 30.....	1	8	29.7±.6	8	29.9±1.2	-.2±1.3
Do.....	2	8	30.2±.3	8	30.1±.4	+ .1±.5

The results of the soil-moisture determinations made in 1916 were practically the same as those secured in 1915. The soil on all the plats contained an abundance of moisture at the time of sampling, and there was no significant difference between the moisture content of the fall-irrigated plats and that of the checks.

The results of the determinations made during the three years may be summarized by the statement that any higher soil-moisture content resulting from fall irrigation was found only at times when the soil on both the fall-irrigated plats and the check plats was well supplied with water and that all significant differences in soil moisture disappeared early in the growing season, so that the crops showed no effects of fall irrigation.

CHARACTER OF SOIL THE DETERMINING FACTOR.

The fact that fall irrigation produced no effect on crop yields at Belle Fourche while it resulted in decidedly higher yields at Scotts-bluff makes it desirable to compare the rainfall and the soil conditions at the two places. The comparison is shown in Table IX.

TABLE IX.—*Rainfall and soil conditions of the Scottsbluff and Belle Fourche Experiment Farms.*

Items of comparison.	Scottsbluff.	Belle Fourche.
Mean precipitation (inches):		
Annual.....	14.47	14.05
Fall period (August to October, inclusive).....	4.96	3.75
Winter period (November to March, inclusive).....	1.35	2.15
Total (August to March, inclusive).....	6.31	5.90
Soil:		
Type.....	Sandy loam.	Pierre clay.
Field moisture-carrying capacity..... per cent ¹	13	27
Wilting coefficient..... do ¹	6	17

¹ These figures, which represent average conditions at the two field stations, were obtained from the Office of Dry-Land Agriculture.

It will be noted that the precipitation at Scottsbluff does not differ materially from that at Belle Fourche, either as to the total quantity or as to the quantities received during the fall and winter periods. The soils represent the essential difference between the two places in relation to fall irrigation. The figures showing moisture-carrying capacity and wilting coefficient indicate something of the wide dissimilarity of the two types of soil. The sandy loam, being coarse grained, has a low moisture-carrying capacity and a low wilting coefficient. On the other hand, the extremely fine-grained Pierre clay has more than double the moisture-carrying capacity of the sandy loam and its wilting coefficient is nearly three times as high.

The soil at Scottsbluff is readily pervious to water to a depth of at least 6 feet, and its permeability is higher when the soil is moist than when it is dry. Knorr ¹ found with this soil that water applied during the regular irrigation season percolated deeper on the plats on which the moisture content was relatively high as a result of fall irrigation than on the check plats where the soil moisture content was comparatively low. This fact, together with the greater quantity of moisture available in the fall-irrigated plats at planting time, is believed to explain the beneficial effects of fall irrigation at Scottsbluff.

The moisture relationships of the soil at Belle Fourche are very different from those at Scottsbluff. At Belle Fourche the soil is practically impervious except when it is dry, and the depth of water percolation depends chiefly upon the extent to which the soil is cracked as a result of dryness. The addition of moisture causes the soil to expand rapidly, and as expansion increases permeability decreases. After making an extensive study of water penetration in these soils, Mathews ² states that "On a dry soil, penetration takes place rapidly to a depth of about 2 feet because of the cracked con-

¹ Knorr, Fritz. Experiments with crops under fall irrigation at the Scottsbluff Reclamation Project Experiment Farm. U. S. Dept. Agr. Bul. 133, 17 p., 5 fig. 1914.

² Mathews, O. R. Water penetration in the gumbo soils of the Belle Fourche Reclamation Project. U. S. Dept. Agr. Bul. 447, p. 11. 1916.

dition of the soil near the surface. After the layer of easily penetrated soil becomes wet, it becomes so swollen and compact that it is nearly impervious, and further water movement is very slow."

The results secured in the fall-irrigation experiments at Belle Fourche are in accord with these observations. The application of irrigation water in the autumn filled the surface soil to its moisture-carrying capacity, but apparently had no effect beyond the third foot. Irrigation water applied uniformly to all plats during the growing season, together with the natural precipitation, equalized the moisture content of the soil in these plats, irrespective of their treatment the previous fall. It is important to note also that an abundance of moisture was present in all the plats at the time of sampling in the spring and early summer and that after this time moisture was supplied by irrigation.

These facts account for the absence of significant differences between the average yields of crops on the fall-irrigated plats and those secured on the check plats. It is possible that if an adequate supply of moisture had not been maintained by irrigation during the growing season the soil-moisture content of the fall-irrigated land would have been higher in the spring than that of the check plats. It seems certain, however, that where crops are properly irrigated during the growing season fall irrigation on this soil will have no material effect.

SUMMARY.

The light precipitation received during the winter months in the Great Plains area commonly causes soil to remain dry from the time crops are harvested until the rainy season the following year. In some soils this deficiency of moisture may have an unfavorable influence on the growth of crops, both by hindering the germination of spring-sown seed and by retarding or preventing the desired movement of the water received as precipitation or applied in irrigation during the growing season.

Fall irrigation has been advocated as a corrective of this condition in irrigated regions. It has been found efficacious on sandy loam soil in western Nebraska, where it resulted in increased soil moisture in the spring and in greater moisture absorption by the soil throughout the irrigation season.

In order to test the practice of fall irrigation on a heavy clay soil, experiments were conducted at the Belle Fourche Experiment Farm, in western South Dakota, in 1914, 1915, and 1916. These experiments included wheat, oats, barley, flax, potatoes, sugar beets, and corn, each crop being grown each year in duplicate tenth-acre plats both on fall-irrigated land and on land which received no fall irrigation.

There were no significant differences between the average yields secured on the fall-irrigated plats and those on the check plats.

Soil-moisture determinations were made in the spring and early summer each year. In 1914 they disclosed no significant differences in the moisture content of the soil resulting from fall irrigation except that in the first two of the three samplings more moisture was found in the first 3 feet of the fall-irrigated plats than in the corresponding depths of the check plats. No effect was noted beyond the third foot. The difference found in the upper 3 feet existed at a time when all the plats contained abundant moisture, and it disappeared before the end of June. No significant differences were found in 1915 or 1916.

The failure of fall irrigation to increase crop yields in these experiments seems to be attributable to the character of the soil at Belle Fourche. This soil is a heavy clay, which will absorb water only when dry and which expands rapidly when moisture is added to it. This expansion so compacts the soil as to make it impervious, so that the storage of water in the lower depths for the use of crops is not practicable.

**PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE ON
RELATED SUBJECTS.**

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Experiments With Crops Under Fall Irrigation at the Scottsbluff Reclamation Project Experiment Farm. (Department Bulletin 133.)
Sugar-beet Growing Under Irrigation. (Farmers' Bulletin 567.)
Irrigated Pastures for Northern Reclamation Projects. (Bureau of Plant Industry, D. R. P.-2.)

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 547



Contribution from Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.



September 19, 1917

COOPERATIVE PURCHASING AND MARKETING ORGANIZATIONS AMONG FARMERS IN THE UNITED STATES.

By O. B. JESNESS, *Assistant in Cooperative Organization*, and W. H. KERR, *Investigator in Market Business Practice*.

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EARLY HISTORY AND GROWTH OF COOPERATIVE ORGANIZATION.

FOUNDATION.

While cooperative organization among the farmers of the United States usually is regarded as a movement of recent origin, farmers' organizations existed in this country as early as the latter part of the eighteenth century. The need for organized effort, however, did not become very apparent until about the middle of the nineteenth century. The first half of the nineteenth century was a period of rapid development in agriculture as well as in other industries, but in so far as the farmer was concerned it was largely a period of individual development. The need felt by the farmer for organized effort about 1850 gave rise to a number of attempts at cooperative purchasing and also brought about the promotion of a number of cooperative stores. Coincident with this movement among farmers, a similar movement was inaugurated in certain of the cities. The establishment of cooperative stores among the factory employees in England had proved so successful that employees, especially in New England cities, profiting by the experience of the

English workers, formed similar associations. A number of organizations were formed, but before any extensive efforts of this kind could be carried out the plans for organization were disrupted by the Civil War.

TREND.

After the close of the Civil War there began a general movement of population toward the virgin lands of the Middle West. The conditions resulting from the rapid development in the Middle West led to a widespread demand for cooperative organization among the farmers of that region. The need of organization was not felt so keenly in the Eastern States, where the population was more dense and business was established on a firmer basis. Affairs in the South were badly disorganized as a result of the Civil War. Extensive changes were necessary in the industrial system, and the readjustment took a considerable length of time. Conditions for organization, therefore, were not as favorable as in the Middle West, where the cooperative movement spread with greatest rapidity after it once had started.

TYPES OF ORGANIZATION.

The history of cooperative organization among farmers since the Civil War consists of the growth and decline of a number of organizations. Many of these organizations were of a local nature, while others were State-wide or national in their scope. Among the latter, the Patrons of Husbandry, or The Grange, as the organization is commonly known, is illustrative of the movement during the late sixties and seventies.¹ The Grange is a farmers' fraternal order established in 1867 for educational and social purposes. The National Grange, which is the central organization, was first formed. Later a large number of local granges were organized and in many of the States these formed State Granges. On account of the demand among farmers, the scope of The Grange was soon enlarged to include such activities as cooperative buying and selling. This movement proved to be very popular among the farmers and resulted in the extension of the organization over a large territory in a comparatively short period.

The early growth of The Grange was confined mainly to the North Central States, as conditions in this section were favorable. The rapid growth of the organization brought it to the notice of the rest of the country, so that the movement soon spread to all parts of the United States. The activities entered upon by The Grange included not only purchasing and marketing ventures but also manufacturing enterprises. Some of the undertakings met with success,

¹ For a more complete history of The Grange see: Aiken, D. W., *The Grange: its origin, progress, and educational purposes*, U. S. Department of Agriculture Special Report 55, 1883; Atkeson, T. C., *Semi-Centennial History of the Patrons of Husbandry*, 1916; Buck, S. J., *The Granger Movement*, Harvard Historical Studies, vol. 19, 1913 (this book contains a comprehensive bibliography relative to this subject).

but a number of difficulties were soon encountered and failure resulted in many instances. This brought about a decline in the movement, so that by 1880 The Grange was practically extinct. Since then, however, it has been revived gradually, so that at present there are a large number of Granges in existence.

Other organizations of farmers were established about the same time as The Grange, or during its decline. Among the organizations which were established during this period were the National Farmers' Alliance and Industrial Union, the Northwestern National Farmers' Alliance, the National Agricultural Wheel, and the Brothers of Freedom.

PRESENT FORMS AND TENDENCIES.

The farmers' purchasing and marketing organizations of the present time may be divided into noncooperative capital stock companies and cooperative organizations. The term "noncooperative capital stock company" is used because an organization may be formed with capital stock and still be cooperative. The noncooperative capital stock company is an organization which distributes its profits according to the capital invested, by means of dividends on capital stock. In a company of this kind there is no limit to the proportion of the capital stock one person may own and the stockholders have as many votes as the number of shares they hold. This makes the capital stock the ruling factor in the organization. In a truly cooperative organization the financial interest of each member is limited, each member has the same voting power, and the savings¹ are distributed by paying a fair rate of interest on the capital invested, and by distributing any further savings in the form of a patronage dividend, proportioned on the amount of business transacted with the organization. Many of the truly cooperative organizations of this country are formed on the capital stock plan, but unlike the ordinary capital stock company there is a limit to the number of shares each may own, the voting powers of all the members are the same, and the stock dividend is limited to a fair rate of interest. Nonstock organizations needing capital usually charge a membership fee or else borrow the necessary money.

It is important to distinguish between stock and nonstock forms of organization because of the bearing which section 6 of the Clayton Act, amending the United States antitrust laws, has on this point.²

It is unfortunate that so many of our farmers' organizations are not formed on a strictly cooperative basis, as this fact undoubtedly has hindered the growth and development of the work of such associations. Among the reasons that can be given for the present

¹ In a strictly cooperative organization the gains made in the business are referred to as savings rather than profits.

² See page 77.

condition of affairs is the fact that only within the last few years have the laws of the various States made specific provision for the organization of truly cooperative associations, and even at the present time a large number of States do not have special laws for this purpose. The present cooperative laws of some of the States are so general in nature that organizations formed in accordance with them do not necessarily embody the underlying principles of cooperation. Therefore a large number of farmers' organizations have been formed under general corporation laws. Many organizations that have been formed under general corporation laws might be reorganized under cooperative laws, where such laws have been passed, with benefit to the members.

Among the general public there is not a clear conception of the differences between the cooperative and noncooperative forms of organization, with the result that noncooperative organizations frequently are called cooperative. Many of these associations have been started by a few persons and are operated for their profit. In support of the practice of paying large stock dividends it usually is stated that, since the stockholders are the ones who are taking the risk and will have to stand any losses that may be encountered, they are entitled to all the profits. Organizations which set aside an adequate reserve to cover any reverses that are likely to be encountered, protect its stockholders. Such organizations are in a position to distribute the profits on a patronage basis after paying the stockholders a stock dividend that represents a fair rate of interest on the money invested. In a noncooperative capital-stock company there is always danger of the ownership of capital stock becoming centered in one or a few individuals. The men in control may not be farmers, or if they are, they may retire from business or move to some other locality, with the result that the men who patronize the organization have no hand in its management.

The incentive to buy up a large amount of the capital stock is removed by limiting the stock dividend to a fair rate of interest on capital invested, while the limitation of the number of shares a member may own effectively provides against the possibility of the stock coming into the hands of a few. Some organizations also place restrictions on the transfer of stock in order to keep the shares in the possession of patrons of the association.

The separation of farmers' organizations in the United States into cooperative and noncooperative groups is by no means a simple task. Some authorities on cooperation insist that an organization must meet all the requirements laid down for cooperative organizations before it can be classed as such; on the other hand, there are persons who class all farmers' organizations as cooperative. If the former method is followed, a large number of the farmers' organiza-

tions in the United States will be excluded from the cooperative class because they fail to live up to cooperative rules in every detail. After all, the main point to be considered is the extent to which the organization works for the benefit of the farmer. An organization may never declare a patronage dividend and still be of profit to all its patrons. A number of the grain elevators, organized on the capital-stock plan, may be cited as examples. They have paid out the profits in the form of stock dividends, yet in many cases have been of benefit to all the patrons because they have paid a higher price for the grain than the farmers had previously received.

The farmers of the United States have engaged in business along a number of different lines. Although the underlying reasons for organizing have been quite similar for the various lines of organization, the histories of their growth are different and present some very instructive facts.

ELEVATORS.

The growth of the farmers' elevator movement was very slow at first but it gradually gained in stability and prominence and began to attract more attention and to receive more favorable treatment from the commission men and railroads. Since 1900 a number of very successful farmers' elevators have been established in the grain-growing States of the Middle West. As they became firmly established they began to assume a wider range of activity than that of handling grain. In some sections it is usual for elevators to ship live stock as well as grain, making a separate live-stock shipping association unnecessary.

Marked success also has been achieved by many farmers' elevators in handling such commodities as coal, lumber, brick, flour, feed, salt, twine, oils, and similar supplies needed by the farmers.

The cooperative elevators have frequently met with opposition from other dealers in these products. Nevertheless they have been able to carry these side lines with a resultant saving to the farmer.

Various estimates have been made of the amount saved by farmers' elevators, but it is difficult to arrive at any definite results because of the far-reaching effects of this form of organization. In many instances the farmers' elevators have increased the price paid the farmer for his grain; when side lines are carried there has often been an additional direct saving; and the dividends paid to the farmers by many of the elevators should also be considered. The increase in returns on products of the farm through the operation of these elevators has had a direct tendency to increase the value of the land in sections where such elevators are located.

Practically all of the important Middle West grain States now have State associations of farmers' elevators. These State associations make it possible for the local companies to keep in touch with one

another and form an effective means of promoting the interests of the farmers' companies. A number of the State associations have formed the National Council of Farmers' Cooperative Associations. This organization is the representative of the farmers' elevator companies in matters of interstate and national importance.

One unfortunate feature of the organization of the farmers' elevator companies is that so many of them fail to live up to cooperative principles. At first the organization of a farmers' elevator was considered a hazardous undertaking and it was asserted that the people who put money into such an undertaking ought to receive its profits in accordance with the amount of their investment. Now that the farmers' elevators are well established, all such organizations that are not cooperative should, wherever possible, adopt the cooperative plan of organization. Some elevators were organized with the assistance of local business men who subscribed for shares of stock, and many of them have experienced difficulty in reorganizing, because the members who are not farmers oppose such a move, as it would reduce the size of their dividends. Some of the farmer members also make this objection. These members should be made to see that the profit has been produced by the handling of the grain and should be distributed accordingly, allowing the stockholders only a fair rate of interest on their investment, if their organization is to be truly cooperative.

CREAMERIES AND CHEESE FACTORIES.

There are approximately 5,500 creameries and 3,500 cheese factories in the United States at the present time. The greater number are located in the territory east of the western boundary of Minnesota and Iowa. The organization of factories for making cheese dates from about the middle of the last century; creameries for the manufacture of butter were started a few years later. The early factories were usually cooperative in form. A number of cooperative creameries were established in New England, in New York, and the surrounding States. Creameries and cheese factories were not established in the North Central States until later, when the country became settled and there was a general change from a system of grain farming to that of diversified crop production. The first cooperative creamery in Minnesota was established in 1889. At the present time there are over 600 enterprises of this kind in that State.

The cooperative creamery has not encountered as well-organized opposition as that which the farmers' elevators have met. At first all creameries were local in character so that competition came principally from privately owned local plants. Since the advent of the hand separator large centralizing plants which receive shipments of cream from an extensive territory have been established. In

some localities these plants have been able to compete successfully with the farmers' organizations, with the result that some cooperative creameries have been forced to discontinue operations.

While the farmers' creameries have not had as systematic competition as the farmers' elevators, there have been other handicaps to their success. In some cases factories have been established before the supply of raw material was large enough to make their operation economical. The farmers have in some instances been the victims of professional promoters. The benefits of a creamery to a community were set forth in such a way that the farmers were led to expect success when it was impossible. Often the promoters received a contract for the creamery equipment for which the farmers paid an exorbitant price. Many creameries have been established in this manner in communities where the number of cows was far too small to make their operation profitable. When such conditions have existed it is not surprising that the cooperative spirit in some of these communities has waned, and that many of the plants which were established have failed.

The farmers' creameries as a general rule are operated in accordance with cooperative principles to a greater extent than are the farmers' elevators. This is accounted for by the differences in the two lines of business. In the grain business the production is seasonal and the market is fluctuating; the farmers also are accustomed to receive their money at the time of delivery of the grain. The production of dairy products is not as seasonal as grain production, and the changes in the market are usually less evident. Patrons of creameries in many places are accustomed to receiving the money for milk or cream once a month. It is therefore a common practice among cooperative creameries to deduct the expenses of operation, set aside whatever is needed as a reserve, and divide the net proceeds of the business among the patrons each month in accordance with the amount of butter fat delivered by each. Many of the farmers' creameries, therefore, are truly cooperative in every sense of the word. Some cooperative creameries set aside a sufficient amount to pay interest on capital invested, while others pay no interest on the capital. Many of the creameries are nonstock organizations; the necessary capital for building and equipping the plant is borrowed, and the money is paid back by a small monthly assessment on the business transacted. In a few cases a creamery has retired its capital stock by purchasing it from the holders with the surplus funds obtained by levying a small monthly assessment on the raw material delivered to the factory.

Not all the farmers' creameries are as near a strictly cooperative type as those described. Some farmers' creameries pay cash for the raw material as it is delivered. Such plants are not able to operate

on a strictly nonprofit basis, as it is necessary for them to buy the butter fat on a safe margin. The surplus funds thus obtained may be prorated quarterly or annually among the patrons, according to the amount of raw material each delivers; or it may be paid to the shareholders in the form of a dividend on capital stock. In some instances large stock dividends have been paid to creamery stockholders, but they are not nearly as common as they are among farmers' elevators.

Privately owned plants generally pay for the milk and cream as it is delivered. This practice has made it necessary for some cooperative creameries to do likewise, especially in districts where the cooperative spirit is not strongly developed and the farmers are not accustomed to the cooperative method of distributing the net returns monthly.

A few creameries have undertaken the marketing of eggs. In such cases an effort usually is made to supply only high-class trade. In order to guarantee the eggs, they are graded and each patron is held responsible for the quality. As the eggs are sold on a quality basis it is possible to obtain higher prices than would be received by the farmers for ordinary ungraded eggs of varying quality.

At a few cooperative creameries a cooperative laundry is operated in connection with the creamery. The creamery patrons may bring their family washing at the same time that they deliver the milk or cream, and as the work is done at cost the expense is not prohibitive.

The activities of the farmers' creameries and cheese factories for the most part have been local in character. A few cooperative dairy organizations have been formed to market the output of a number of creameries and cheese factories, but as yet this movement has not become very general. Butter makers, cheese makers, creamery officials, and dairymen have formed a number of State and National associations, which compare with similar associations among operators of elevators. These organizations are primarily for educational and protective purposes and also form a medium for holding contests and exhibits of the various dairy products.

STORES.

The cooperative store is an older form of organization than either the farmers' elevator or the creamery. A number of such stores were in existence about the middle of the last century, especially in the New England States. The Lowell Cooperative Association, which was established in 1876, is an example of a store that has been in operation for a long period. The seventy-seventh semiannual report of this store for the six months' period ending June 30, 1914, shows the distribution of about \$5,000 as patronage dividends, indicating that the organization is cooperative.



FIG. 1.—A BUSY DAY—FARMERS' GRAIN ELEVATOR.



FIG. 2.—SHIPPING DAY—FARMERS' LIVE STOCK SHIPPING ASSOCIATION.



FIG. 1.—FARMERS' COOPERATIVE CREAMERY AND CHEESE FACTORY.

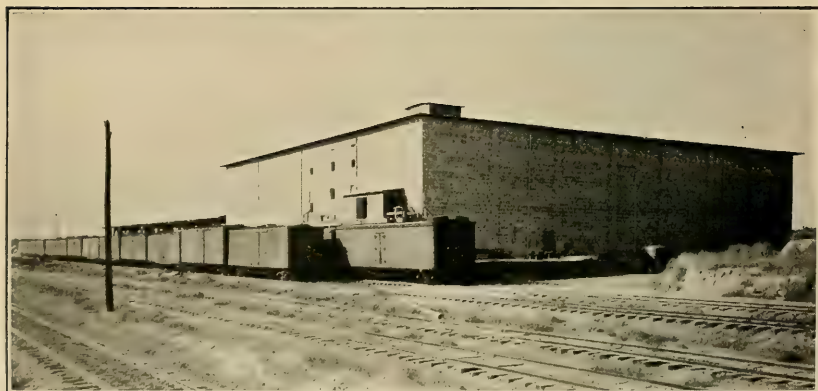


FIG. 2.—COLD-STORAGE PLANT—COOPERATIVE FRUIT MARKETING ASSOCIATION.

For various reasons a large number of failures have occurred among the farmers' cooperative stores. This line of business is not as well understood by the farmer as is the elevator or creamery business and he frequently fails to take into consideration the problems connected with the management of a store. The member of a creamery or an elevator association is in a better position to keep in touch with the business, while the members of a cooperative store association usually leave the supervision of its affairs entirely in the hands of the manager. Although this is a satisfactory arrangement in some cases, the manager is not always capable, and in some cases the store has even suffered through wilful mismanagement. Another factor which sometimes causes failure is the fact that the farmers have been led to expect greater returns than it is possible to secure, so that the members are disappointed with the results obtained and cease to support the enterprise.

The failure of some cooperative stores is accounted for by the fact that they have not been operated in accordance with the underlying principles of cooperation. The English stores, based on the Rochdale plan of organization, are often cited as examples of successful cooperative stores. These stores embody the true principles of cooperation in that the voting power and financial interests of the members are limited, and the profits are distributed according to patronage.

FRUIT AND PRODUCE ASSOCIATIONS.

The method of marketing the fruit crop is very complex because of the perishability of the commodities handled and because a large proportion of the fruit is produced in certain restricted localities from which it must be distributed to all parts of the United States and foreign countries. The fruit growers of the United States have been attracted by the possibilities of cooperative fruit marketing, and during the last 25 years a large number of associations have been formed which have been very successful.

The most successful fruit-marketing associations are found in the Pacific Coast States, among the citrus fruit growers of California and the apple growers of the North Pacific States. These organizations owe a large part of their success to the fact that they do more than merely attend to the actual selling of the fruit. The fruit crop varies in quality; therefore the associations have assisted in standardizing the growing of the fruit, and in many instances have taken charge of the sorting and packing. Thus a large quantity of fruit of the same grade and quality is assured, and it is possible to establish trade-marked brands which become known to the trade. By conducting advertising campaigns on an extensive scale consumers are reached in large numbers, the consumption of the fruit is increased, a demand is insured, and brands are established on the market. A single grower

or even a number of growers can not accomplish very much in this manner, but when a number of local organizations of growers form a central organization, the volume of business is sufficiently large to render it practicable to conduct such work on an extensive scale. The local fruit-marketing associations have had greater need for central organizations than the local elevator and creamery associations, consequently such organizations have played a more important part in the case of fruit associations.

While the most extensive organizations for the marketing of fruit are found in the Western States, there are a number of such associations in other parts of the United States. Most of them are found in regions where fruit growing is an important industry, but some are found in places where this industry is only a side line. Fruit-marketing organizations formed in regions where the members are not dependent on the fruit crop for a living frequently are not very successful.

In some of the truck-growing districts there are extensive organizations for the marketing of truck crops. Like some of the fruit associations, they have been instrumental in establishing uniform grades and in selling them under trade-marked brands. In addition, a number of local organizations formed for the purpose of marketing truck or vegetable crops are scattered over the country. A number of such associations have been organized for the sole purpose of marketing potatoes, while others which began with potatoes now handle a variety of commodities.

COTTON ORGANIZATIONS.

The cotton growers of the South have a number of cooperative organizations, but the cotton grower is not as well organized as the fruit grower, the grain farmer, or the dairy farmer. Because of the common custom of securing advances on their growing crop from merchants and others, the marketing of the cotton crop, to a large extent, has been taken out of the farmers' hands. This practice has stood in the way of any extensive organization among the growers for marketing purposes. While the movement is not yet general, there are a number of selling associations, warehouses, cotton gins, and oil mills that are controlled by growers.

COOPERATIVE PURCHASING.

The cooperative purchase of supplies has been carried on among the farmers of the United States for a long time. In some cases the farmers have associations organized for this special purpose, but in a great number of instances it is carried on in an informal way, without a definite organization. The selling associations of farmers frequently serve as mediums for the cooperative purchase of supplies. Thus the fruit associations often buy supplies needed by the fruit growers, and the same custom is followed by other cooperative organizations.

STATISTICS OF COOPERATION.

METHOD USED IN SECURING INFORMATION.

In January, 1914, the Office of Markets and Rural Organization undertook a survey of cooperative marketing in the United States. The first step necessary in a study of this kind was to secure a list of the names of the cooperative marketing organizations of the United States. A nucleus for such a list was secured from the mailing list of the department and to this were added names received from various other sources. Through the Bureau of Crop Estimates of the Department of Agriculture a letter was sent to the voluntary crop correspondents scattered throughout the United States. This letter requested the correspondent to furnish the department with the names and addresses of all the cooperative marketing organizations in his territory. Through the States Relations Service of the department additional names were secured from the county agents. In addition, some of the agricultural colleges, secretaries of state, and State departments of agriculture furnished such lists of organizations in their States as were available. From these various sources approximately 12,500 names of farmers' purchasing and marketing organizations were secured.

Questionnaires which called for information relating to the plan of organization, the number of members, the kind and volume of business, the method of distributing profits, and other items were sent to the organizations on the list compiled by the Department of Agriculture. Many were returned with the information that the organizations had discontinued business. On account of inaccuracies in the names of some of the organizations reported, there were some duplicates on the list. In some instances the names proved to be those of private concerns, not farmers' or cooperative organizations in any sense. These corrections reduced the number on the list to about 12,300. In all, 5,424 organizations have been included in the final summations (see Table I). This means that more than 6,000 organizations have failed to report. It is believed that many of these are not actively engaged in business, because they have failed to reply to repeated requests for information. It is also probable that some of this number failed to reply because they are private concerns and therefore do not come within the scope of this survey.

All of the strictly private concerns and the stock companies in which a few stockholders appear to operate the business principally for their own benefit have been eliminated, in order to make the survey include as nearly as possible only farmers' cooperative marketing organizations. While no hard and fast rules of classification have been laid down, an attempt has been made to include all of those organizations which are composed of a number of farmers and are operated primarily for the benefit of the patrons. While a number of these organizations would not be classed as cooperative under

a strict interpretation of the definition of cooperation, it has been thought best to include all of those in which the benefits of the business to some extent accrue to the farmer patrons, which benefits would not have been secured from a private company, owned and operated for the sole purpose of making money in the business.

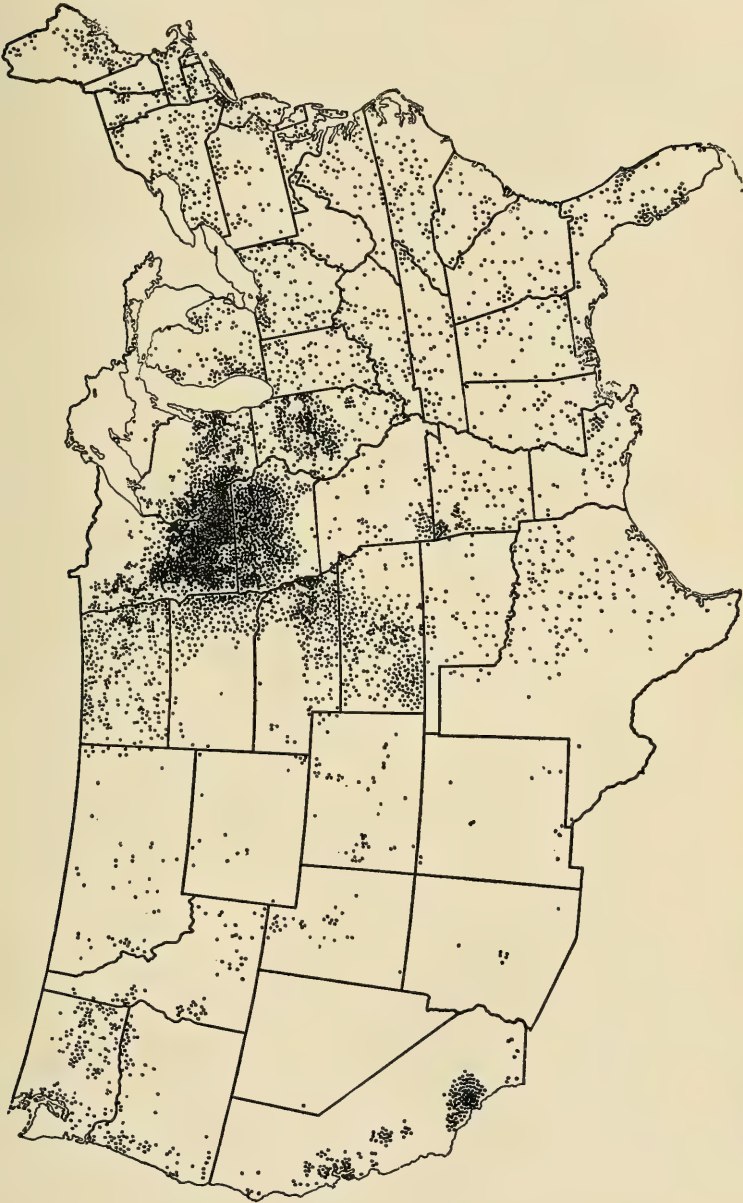
There are undoubtedly a number of organizations whose names and addresses have not yet been secured, and probably some of those that failed to reply are actively engaged in business; consequently this survey does not cover all of the organizations. It is believed, however, that those included represent most of the going concerns, and that the information secured is fairly complete. Many cooperative associations reach the point of organization only, as is shown by the large number of letters received by the Department of Agriculture from farmers, stating that an association had been formed in their community, but as yet had failed to do business to any considerable extent.

DESCRIPTION OF TABLES.

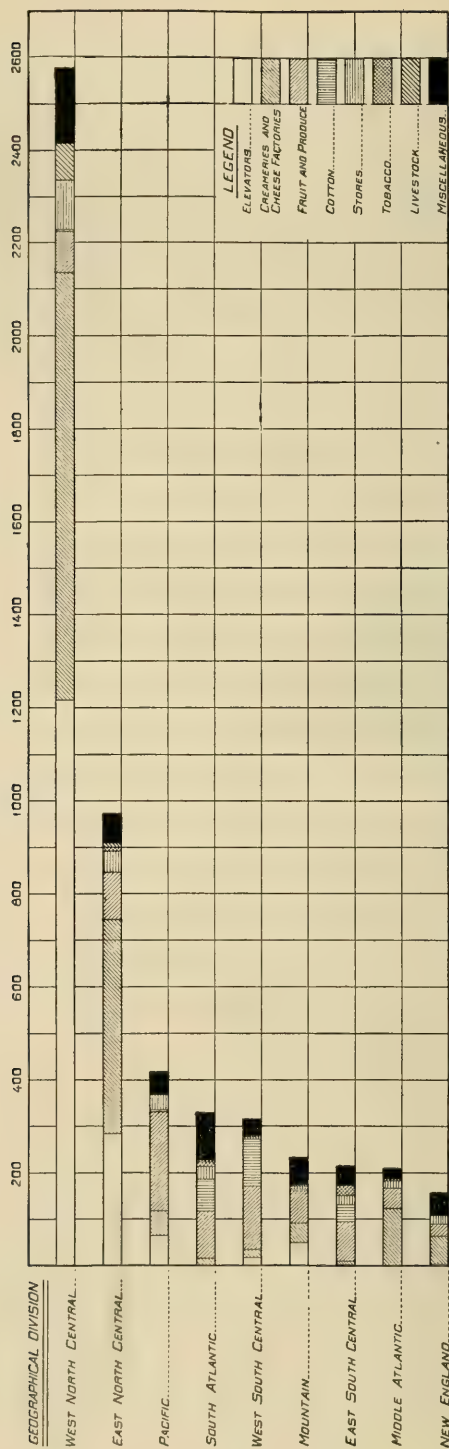
The information secured from the survey has been summarized and is presented in Tables I to III, inclusive. In Table I the total number of farmers' organizations reporting to the Office of Markets and Rural Organization, for each class of business, is shown by States as well as for the United States as a whole. (See also Charts 2 and 3.) The column headed "Grain elevators and warehouses" includes the grain warehouses common in the North Pacific States as well as the regular grain elevators. Creameries and cheese factories have been grouped together because in a number of instances one plant makes both butter and cheese. As many associations handle both fruit and produce, these two forms have been grouped in the same manner. The miscellaneous class includes the enterprises that could not be grouped in any of the other classes. Of the 5,424 organizations included in this report, 1,637 are grain elevators and warehouses, 1,708 creameries and cheese factories, 871 fruit and produce, 213 cotton, 275 store, 43 tobacco, 96 live stock, and 581 miscellaneous associations.

TABLE I.—*Total number of farmers' organizations reporting for each class of business, by States.*

State.	Total number reporting.	Kind of business.							
		Grain elevator and warehouse.	Creameries and cheese factories.	Fruit and produce.	Cotton.	Stores.	Tobacco.	Live stock.	Miscellaneous.
Alabama.....	51	.....	.....	26	19	1	.....	1	4
Arizona.....	7	.....	.....	3	1	.....	.....	.....	3
Arkansas.....	89	.....	1	63	15	3	.....	.....	7
California.....	197	.....	26	124	2	11	.....	.....	34
Colorado.....	53	3	13	28	.....	1	.....	.....	8
Connecticut.....	20	.....	14	3	.....	.....	.....	.....	3
Delaware.....	5	.....	3	1	.....	.....	.....	.....	1
Florida.....	69	.....	.....	55	2	.....	.....	.....	12
Georgia.....	55	.....	.....	5	44	2	.....	.....	4
Idaho.....	59	9	6	17	.....	1	.....	.....	26
Illinois.....	263	192	34	11	.....	2	.....	.....	24

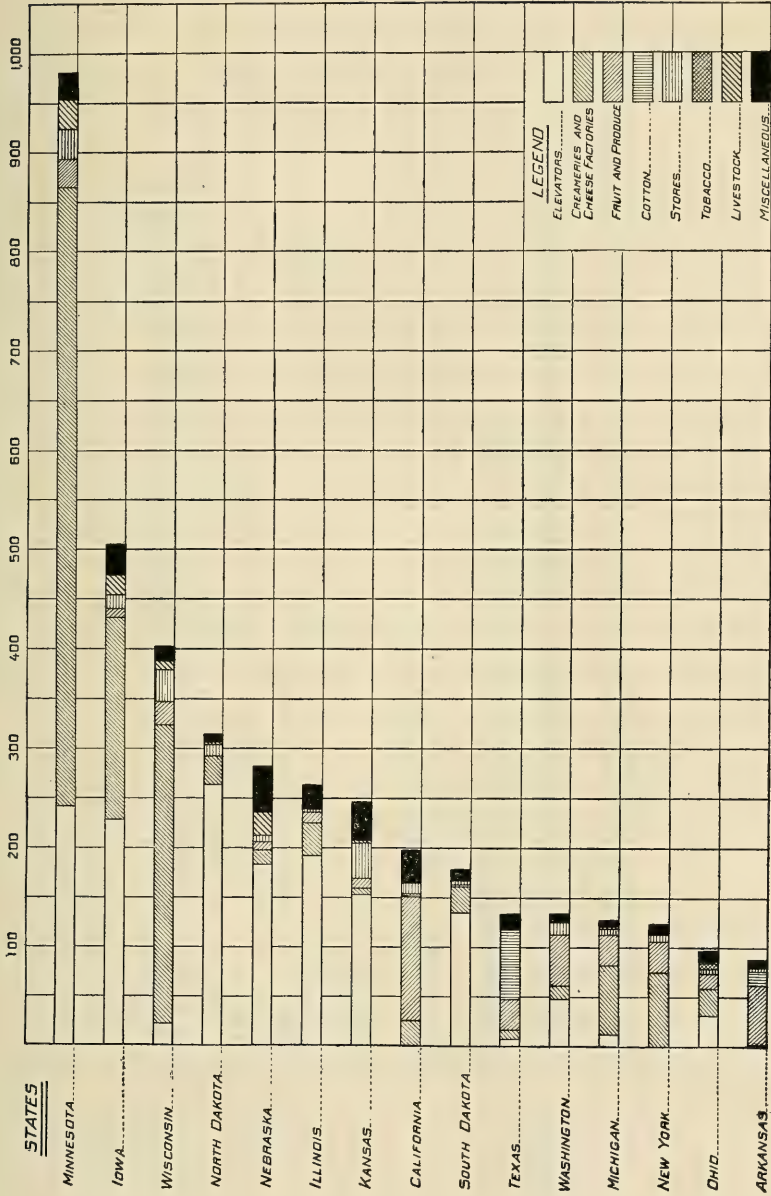


LOCATION OF ALL COOPERATIVE ORGANIZATIONS REPORTING TO THE OFFICE OF MARKETS AND RURAL ORGANIZATION.

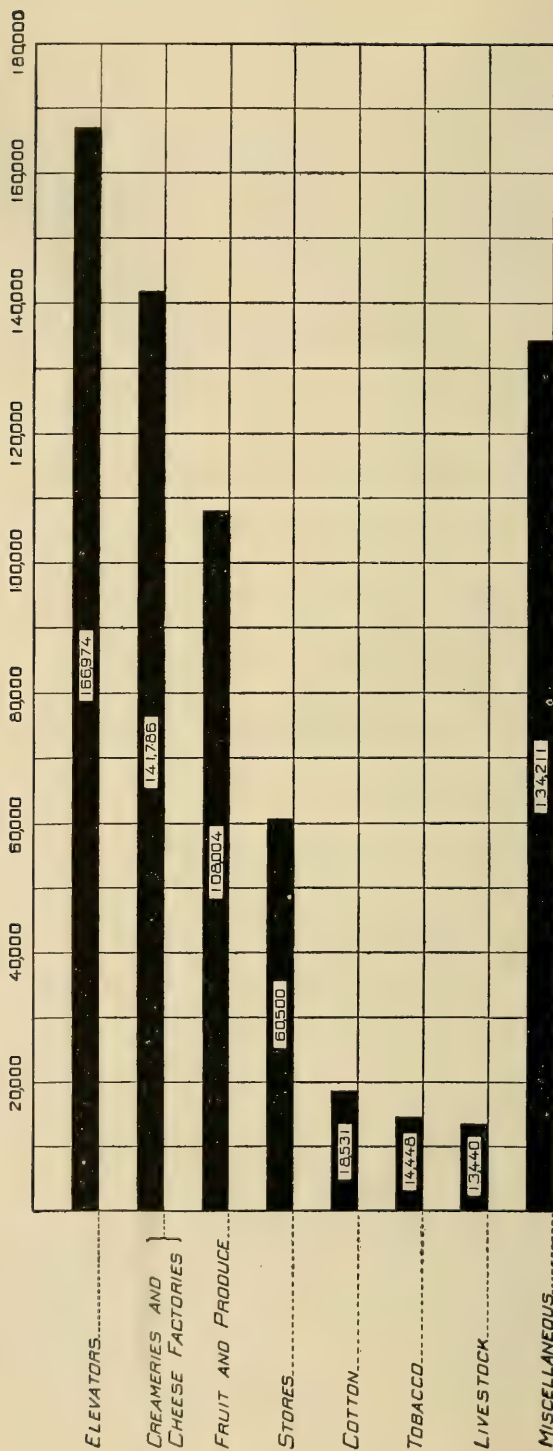


NUMBER OF COOPERATIVE ORGANIZATIONS BY CLASS IN GEOGRAPHICAL DIVISIONS.

CHART 3.



NUMBER OF ORGANIZATIONS BY CLASS IN FIFTEEN LEADING COOPERATIVE STATES.



MEMBERSHIP OF ALL COOPERATIVE ORGANIZATIONS.

TABLE I.—Total number of farmers' organizations reporting for each class of business, by States—Continued.

State.	Total number reporting.	Kind of business.							
		Grain elevator and warehouse.	Creameries and cheese factories.	Fruit and produce.	Cotton.	Stores.	Tobacco.	Live stock.	Miscellaneous.
Indiana.....	84	27	27	19					11
Iowa.....	505	228	204	8		14		20	31
Kansas.....	246	153	6	10		36		2	39
Kentucky.....	66	1	6	15		6	21		17
Louisiana.....	44			34	3				
Maine.....	71	1	7	19		5			39
Maryland.....	19		1	8					10
Massachusetts.....	31		10	5		11			5
Michigan.....	127	12	70	31		7		2	5
Minnesota.....	980	241	624	28		30		30	27
Mississippi.....	42			26	11		1		4
Missouri.....	73	13	15	34	1	6		1	3
Montana.....	51	27	12	7		2			3
Nebraska.....	282	183	15	7		6		25	46
Nevada.....	2		1						1
New Hampshire.....	8		8						
New Jersey.....	20		2	9		4			5
New Mexico.....	13			3					10
New York.....	124		75	32		7			10
North Carolina.....	74		4	9	10	17	5	1	28
North Dakota.....	313	264	29			12		2	6
Ohio.....	97	31	29	16		4	7	1	9
Oklahoma.....	48	11	8	9	13	2		2	3
Oregon.....	85	16	16	40		8			5
Pennsylvania.....	66		48	4		4	2		8
Rhode Island.....	4					3			1
South Carolina.....	37		1	7	14	2	1		12
South Dakota.....	178	135	26	1	7	4			12
Tennessee.....	56		2	18	7	13	1		15
Texas.....	184	7	9	31	71				16
Utah.....	31	4	9	12		1			5
Vermont.....	23		22						1
Virginia.....	58		8	13		3	5	1	28
Washington.....	134	48	14	52		12			8
West Virginia.....	12			4		1			7
Wisconsin.....	402	23	301	24		32		7	15
Wyoming.....	16	8	2			2		1	3
United States..	5,424	1,637	1,708	871	213	275	43	96	581

Table II shows the type of organization, the annual volume of business, and membership for the organizations reporting on these points, arranged according to classes for each State, with a similar arrangement for all classes for the entire United States. (See also Charts 4 and 8.) So far as possible, the type of organization has been indicated. Those that conduct their business as an ordinary stock company have been placed in one class and those that operate on a more truly cooperative basis have been placed in the other class. This does not mean that all the associations in the last-named class are organizations without capital stock; on the contrary, a large number of them have capital stock because this is the common form of organization among farmers' companies. An association can be truly cooperative even though it is formed on the stock-company plan. As has been stated, an effort was made to exclude all organizations owned and operated for the benefit of a few stockholders. Those with a large number of stockholders which appear to operate principally for the benefit of the patrons have been included, even though they are not strictly cooperative in nature.

Colorado:												
Elevators.....	1	2	.....	8	.....	2	375,000	1	250,000	2	450	225
Creameries and cheese factories.....	8	5	.....	11,701	.....	11	138,471	2	24,314	9	246	27
Fruit and produce.....	21	14	2,508,175	18	2,042,620	9	612,150	1	125,000	22	3,691	163
Stores.....	.....	1	.....	.....	150,000	1	150,000	.....	.....	80	80	.....
Miscellaneous.....	1	7	110,000	3	191,630	2	16,630	.....	.....	7	715	102
Total.....	31	22	2,618,175	29	2,345,951	25	1,302,251	4	399,314	41	5,082	124
Average.....	.....	.....	174,545	.....	80,895	.....	52,090	.....	99,829	.....	.....	.....
Connecticut:												
Creameries and cheese factories.....	7	6	111,900	11	560,600	9	495,111	1	24,408	9	1,247	139
Fruit and produce.....	.....	2	.....	1	5,500	.....	4,500	.....	.....	3	130	43
Miscellaneous.....	1	1	50,000	1	47,000	1	.....	.....	.....	3	465	155
Total.....	8	9	161,900	13	613,100	10	499,611	1	24,408	15	1,842	123
Average.....	.....	.....	40,475	.....	47,162	.....	49,961	.....	24,408	.....	.....	.....
Delaware:												
Creameries and cheese factories.....	.....	1	.....	2	40,075	2	44,309	.....	.....	.....	.....	.....
Fruit and produce.....	1	1	500,000	1	500,000	.....	20,000	1	.....	1	1,200	1,200
Miscellaneous.....	1	.....	.....	1	20,000	1	.....	.....	.....	1	3	3
Total.....	1	1	500,000	4	560,075	3	64,309	.....	.....	2	1,203	602
Average.....	.....	.....	500,000	.....	140,019	.....	21,436	.....	.....	.....	.....	.....
Florida:												
Fruits and produce.....	3	46	90,000	25	1,682,200	27	1,988,200	5	82,500	50	2,053	41
Cotton.....	2	.....	.....	.....	.....	.....	.....	.....	.....	15	15	15
Miscellaneous.....	2	7	.....	4	300,400	6	352,350	.....	.....	7	467	67
Total.....	7	53	90,000	29	1,982,600	33	2,340,550	5	82,500	58	2,535	44
Average.....	.....	.....	90,000	.....	68,366	.....	70,926	.....	16,500	.....	.....	.....
Georgia:												
Fruit and produce.....	1	4	2,250,000	2	11,000	2	13,000	1	5,000	5	522	104
Cotton.....	31	9	.....	14	1,952,800	12	1,901,660	1	3,000	25	1,873	75
Stores.....	.....	2	.....	.....	1	1	45,000	1	48,000	2	100	50
Miscellaneous.....	2	1	.....	3	64,000	3	62,000	.....	.....	3	231	77
Total.....	34	16	2,250,000	19	2,027,800	18	2,021,660	3	56,000	35	2,731	78
Average.....	.....	.....	2,250,000	.....	106,726	.....	112,315	.....	18,667	.....	.....	.....
Idaho:												
Elevators.....	7	1	3,000	5	104,807	3	117,500	.....	.....	9	508	56
Creameries and cheese factories.....	1	5	4,000	2	57,000	4	148,000	1	150,000	6	902	150
Fruit and produce.....	5	12	.....	9	458,000	7	275,760	.....	.....	15	1,188	79
Stores.....	1	.....	.....	1	5,000	1	10,000	1	.....	1	27	27
Miscellaneous.....	7	15	.....	11	1,433,400	17	2,142,831	.....	.....	24	12,038	502
Total.....	21	33	7,000	28	2,118,207	32	2,694,091	1	150,000	55	14,663	267
Average.....	.....	.....	3,500	.....	75,650	.....	84,190	.....	150,000	.....	.....	.....

Live stock.....	1	111,282	2	171,262	1	27,000	7	348,500	2	370	185
Miscellaneous.....	15	320,000	16	3,331,203	24	4,129,353	.....	.....	31	4,144	134
Total.....	131	6,641,986	128	13,893,671	139	21,364,329	32	3,680,033	221	25,707	116
Average.....	.....	158,143	.....	108,544	.....	153,700	.....	115,001	.....	.....	.....
Kentucky:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Elevators.....	1	.....	1	100,000	1	125,000	.....	.....	1	85	85
Creameries and cheese factories.....	4	33,200	4	43,200	1	8,000	.....	.....	3	188	63
Fruit and produce.....	7	401,700	7	401,700	9	272,264	2	2,550	13	1,023	79
Stores.....	4	76,000	4	92,000	4	92,000	.....	.....	5	917	133
Tobacco.....	17	1,580,489	10	1,580,489	9	1,718,103	1	150,000	11	7,345	668
Miscellaneous.....	5	293,080	8	293,080	8	291,000	1	4,000	13	2,060	158
Total.....	38	33,200	34	2,494,479	32	2,506,367	4	156,550	46	11,618	253
Average.....	.....	11,067	.....	73,367	.....	78,324	.....	39,138	.....	.....	.....
Louisiana:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fruit and produce.....	11	426,979	16	482,683	15	254,726	6	287,150	32	3,201	100
Cotton.....	2	50,000	1	50,000	2	60,000	.....	.....	1	5	5
Miscellaneous.....	6	75,000	5	282,000	3	118,000	.....	.....	7	748	107
Total.....	19	501,979	22	824,683	20	432,726	6	287,150	40	3,954	99
Average.....	.....	125,495	.....	37,486	.....	21,636	.....	47,858	.....	.....	.....
Maine:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Elevators.....	1	.....	2	2,059,545	4	2,196,151	2	140,000	3	244	81
Creameries and cheese factories.....	2	51,000	8	216,800	6	34,170	2	5,000	19	1,203	63
Fruit and produce.....	13	123,000	1	26,000	3	84,000	2	78,000	3	681	227
Stores.....	1	29,000	15	816,137	18	1,592,870	.....	.....	38	4,911	130
Miscellaneous.....	34	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total.....	51	203,000	26	3,118,482	31	3,847,191	6	223,000	63	7,039	112
Average.....	.....	40,600	.....	119,942	.....	124,103	.....	37,167	.....	.....	.....
Maryland:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Creameries and cheese factories.....	.....	.....	1	5,000	1	5,000	.....	.....	1	54	54
Fruit and produce.....	6	1,250,000	3	1,289,559	4	80,304	1	5,000	8	1,014	127
Miscellaneous.....	4	194,000	3	194,000	3	203,000	1	30,000	10	691	69
Total.....	10	1,250,000	7	1,488,559	8	288,304	2	35,000	19	1,759	93
Average.....	.....	1,250,000	.....	212,651	.....	36,038	.....	17,500	.....	.....	.....
Massachusetts:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Creameries and cheese factories.....	5	51,470	7	256,202	4	70,000	.....	.....	8	657	82
Fruit and produce.....	1	998,000	3	1,210,603	1	3,000	.....	.....	5	693	139
Stores.....	4	404,795	6	404,795	8	579,223	3	172,847	10	4,515	452
Miscellaneous.....	2	50,000	2	50,000	4	159,000	.....	.....	4	134	34
Total.....	12	1,019,470	18	1,921,600	17	811,223	3	172,847	27	5,999	223
Average.....	.....	339,823	.....	106,756	.....	47,719	.....	57,616	.....	.....	.....

Cotton.....	1	.....	1	65,000	1	35,000	.....	1	14	14
Stores.....	5	.....	2	27,000	5	139,800	.....	5	340	68
Live stock.....	1	.....	.....	.....	1	2,000	.....	.....	.....	.....
Miscellaneous.....	2	.....	1	17,000	3	28,551	.....	8	568	189
Total.....	36	34	45	2,023,420	51	2,406,767	7	65	129,800	94
Average.....	.....	.....	.....	44,965	.....	47,192	.....	.....	18,543	.....
Montana:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Elevators.....	12	14	8	1,485,099	13	2,448,822	.....	23	735,000	105
Creameries and cheese factories.....	8	5	8	410,736	6	721,732	.....	7	663	95
Fruit and produce.....	2	4	4	66,900	3	39,000	1	6	489	82
Stores.....	1	1	2	26,000	1	50,000	.....	2	123	62
Miscellaneous.....	1	1	2	236,000	2	245,000	.....	2	73	37
Total.....	24	25	23	2,224,735	25	3,504,554	6	40	745,000	94
Average.....	.....	.....	.....	96,728	.....	140,182	.....	.....	124,167	.....
Nebraska:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Elevators.....	137	44	83	11,195,185	105	14,440,269	19	173	425,000	99
Creameries and cheese factories.....	6	9	6	550,000	7	632,918	.....	11	1,227	111
Fruit and produce.....	3	4	6	33,852	6	388,002	.....	6	1,701	117
Stores.....	4	2	1	36,000	1	2,000	1	4	463	116
Live stock.....	8	15	9	746,222	14	1,201,559	4	24	3,817	159
Miscellaneous.....	21	21	17	1,816,410	27	3,398,245	4	37	3,293	89
Total.....	179	95	122	14,677,609	160	20,062,993	28	255	1,470,000	105
Average.....	.....	.....	.....	184,246	.....	125,384	.....	.....	52,500	.....
Nevada:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Creameries and cheese factories.....	.....	1	1	7,850	1	8,000	.....	1	1,265	.....
Miscellaneous.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....
Total.....	.....	2	1	7,850	1	8,000	.....	1	1,265	1,265
Average.....	.....	.....	.....	7,850	.....	8,000	.....	.....	.....	.....
New Hampshire:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Creameries and cheese factories.....	2	6	5	121,158	5	121,146	2	5	35,000	239
Average.....	.....	.....	.....	24,231	.....	24,229	.....	.....	17,500	.....
New Jersey:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Creameries and cheese factories.....	1	1	2	555,274	2	687,150	.....	2	52	26
Fruit and produce.....	5	2	3	1,449,400	4	1,175,956	1	8	3,585	448
Stores.....	1	2	2	126,000	2	146,154	1	4	1,001	250
Miscellaneous.....	1	3	1	500	.....	.....	.....	3	1,352	451
Total.....	8	8	8	2,155,174	8	2,009,260	2	17	13,654	352
Average.....	.....	.....	.....	269,397	.....	251,158	.....	.....	6,827	.....

TABLE II.—Type of organization, volume of business, and number of members of organizations reporting, by States and kinds of business—Continued.

	Type of organization.		Volume of business.						Membership.		
			1912		1913		1914		1915		
	Stock company.	Co-operative.	Num-ber re- porting.	Volume.	Num-ber re- porting.	Volume.	Num-ber re- porting.	Volume.	Num-ber re- porting.	Volume.	Aver- age.
New Mexico:											
Fruit and produce.	2				2	\$37,500		\$136,251	1	\$100,000	40
Miscellaneous.	5	5	3	\$287,278	4	413,967	3	286,500			76
Total.	7	5	3	287,278	6	451,467	6	422,751	1	100,000	66
Average.				95,759		75,241		70,458			
New York:											
Creameries and cheese factories.	33	33	10	518,615	45	2,059,166	47	1,934,365	7	182,846	49
Fruit and produce.	11	15	5	4,435,219	18	9,244,842	14	2,769,014	1	1,500,000	152
Stores.	3	2	5	22,000	5	209,489	5	223,409			151
Miscellaneous.	2	7	1	5,000	3	66,500	5	308,576	1	150,000	93
Total.	49	57	17	4,980,834	71	11,579,997	71	5,241,364	9	1,832,846	85
Average.				292,990		163,099		73,822		203,650	
North Carolina:											
Creameries and cheese factories.	1	3	1	100,000	1	23,000	1	120,000	1	240,000	161
Fruit and produce.	2	7	7	109,500	6	109,500	6	154,000	8	1,920	240
Cotton.	7	1	1	15,000	6	3,727,000	4	4,620,000	5	677	135
Stores.	11	5	2	57,000	11	263,384	9	336,400	15	1,551	103
Tobacco.	3	1	1		1	725,000	1	725,000	4	1,696	424
Live stock.									1	50	50
Miscellaneous.	3	19	2	25,000	14	147,848	12	94,200	1	1,200	68
Total.	27	37	6	197,000	40	4,995,732	33	6,049,600	2	241,200	136
Average.				32,833		124,893		183,321		120,600	
North Dakota:											
Elevators.	162	98	70	10,955,090	138	19,616,065	120	15,904,434	58	10,034,157	74
Creameries and cheese factories.	15	16	5	181,809	16	322,027	16	234,264	3	37,000	47
Stores.	10	2	1	36,000	4	112,085	4	86,112	1	40,000	74
Live stock.								13,288	2	75,000	93
Miscellaneous.	5	1	4		4	71,857	4	670,000	2	225,000	80
Total.	192	119	76	11,172,899	162	20,122,034	145	16,908,098	66	10,411,157	73
Average.				147,012		124,210		116,608		157,745	

Ohio:	Elevators.....	29	.....	5	370,371	16	1,829,701	13	1,545,500	4	300,000	28	2,977	106
	Creameries and cheese factories.....	21	6	4	82,609	23	811,772	13	2,003,317	1	25,000	25	5,709	228
	Fruit and produce.....	7	9	1	45,000	9	909,827	8	935,827	1	80,000	14	8,779	63
	Stores.....	1	3	.....	.....	1	155,000	1	180,000	.....	.....	4	1,010	253
	Tobacco.....	7	.....	.....	.....	7	249,931	3	250,576	.....	.....	7	551	79
	Live stock.....	.....	1	.....	.....	1	3,275	1	9,500	.....	.....	1	90	90
	Miscellaneous.....	1	5	1	4,352	4	17,000	8	78,200	2	26,487	6	1,203	201
	Total.....	66	24	11	502,332	61	3,976,506	56	5,002,920	8	431,487	85	12,419	146
	Average.....	.....	.....	.....	43,667	.....	65,189	.....	89,338	.....	53,936	.....	.....	.....
	Oklahoma:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oklahoma:	Elevators.....	8	2	2	129,330	8	631,000	7	997,000	3	490,000	9	794	88
	Creameries and cheese factories.....	4	4	1	16,000	3	66,573	4	108,317	2	40,759	6	485	81
	Fruit and produce.....	2	6	.....	.....	2	19,000	3	45,000	2	4,500	7	313	45
	Cotton.....	12	1	.....	.....	8	419,757	9	577,558	2	42,500	11	688	63
	Stores.....	2	1	1	110,000	.....	.....	1	15,870	.....	.....	2	601	301
	Live stock.....	2	.....	.....	.....	1	55,000	1	150,000	.....	.....	2	138	69
	Miscellaneous.....	1	2	.....	.....	.....	.....	1	63,000	1	14	2	61	31
	Total.....	31	15	4	255,330	22	1,191,330	26	1,959,745	10	577,773	39	3,080	79
	Average.....	.....	.....	.....	63,833	.....	54,151	.....	75,375	.....	57,777	.....	.....	.....
	Oregon:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oregon:	Elevators.....	12	2	1	275,000	14	1,650,229	13	2,151,085	1	500,000	11	693	63
	Creameries and cheese factories.....	7	8	2	535,388	5	754,757	9	324,178	5	61,000	14	774	55
	Fruit and produce.....	28	11	9	2,197,646	20	4,220,836	15	888,592	1	25,000	35	4,035	115
	Stores.....	2	4	.....	.....	2	160,289	6	448,456	.....	.....	7	3,541	506
	Miscellaneous.....	.....	4	.....	.....	1	36,000	1	90,000	.....	.....	3	184	61
	Total.....	49	29	12	3,008,034	42	6,822,221	44	3,902,311	7	586,000	70	9,227	132
	Average.....	.....	.....	.....	250,670	.....	162,434	.....	88,689	.....	88,714	.....	.....	.....
	Pennsylvania:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Creameries and cheese factories.....	25	19	9	338,956	30	757,212	33	1,003,486	10	514,234	38	1,937	51
	Fruit and produce.....	2	2	1	442,533	1	390,500	.....	.....	1	75,000	4	308	77
Pennsylvania:	Stores.....	1	4	.....	.....	.....	.....	4	66,200	3	67,000	4	422	106
	Tobacco.....	4	4	3	207,763	5	337,200	4	97,000	.....	.....	2	630	315
	Miscellaneous.....	.....	.....	.....	.....	.....	.....	.....	99,500	1	100,000	8	42,292	5,287
	Total.....	32	30	13	989,252	36	1,484,912	43	1,266,186	15	756,234	56	45,589	814
	Average.....	.....	.....	.....	76,066	.....	41,248	.....	26,446	.....	50,416	.....	.....	.....
	Rhode Island:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Stores.....	2	1	.....	.....	2	101,630	1	34,000	.....	.....	3	642	214
	Miscellaneous.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	1	180	180
	Total.....	2	2	.....	.....	2	101,630	1	34,000	.....	.....	4	822	206
	Average.....	.....	.....	.....	.....	.....	50,815	.....	34,000	.....	.....	.....	.....	.....

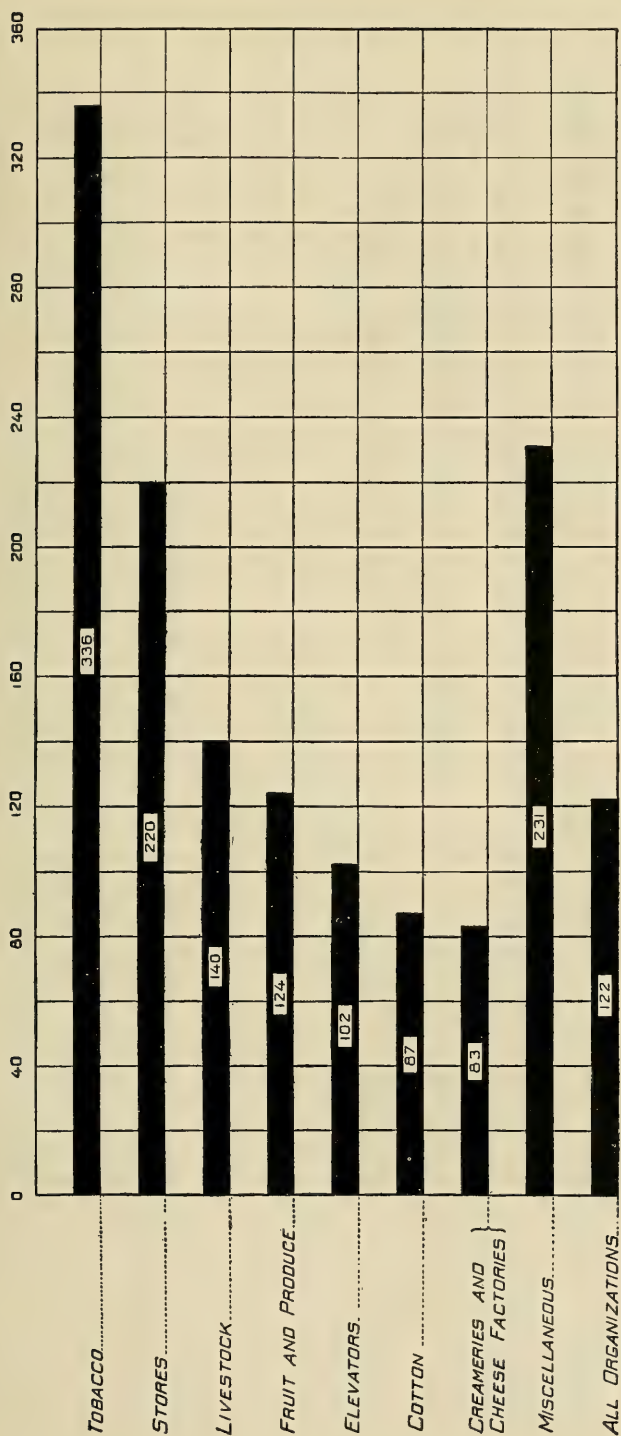
TABLE II. — *Type of organization, volume of business, and number of members of organizations reporting, by States and kinds of business—Continued.*

State.	Type of organization.		Volume of business.								Membership.		
			1912		1913		1914		1915				
	Stock com-pany.	Coop-erative.	Num-ber re- porting.	Volume.	Num-ber re- porting.	Volume.	Num-ber re- porting.	Volume.	Num-ber re- porting.	Volume.	Total.	Aver- age.	
South Carolina:													
Creameries and cheese factories.....		1						1	\$5,500	1	\$5,500	56	
Fruit and produce.....		7						7	17,700	3	526,935	357	51
Cotton.....	10	2			6	\$466,500	6	297,500				551	61
Stores.....	2				1	4,500	2	48,000				8	
Tobacco.....	1											18	4
Miscellaneous.....	5	6			6	319,222	7	329,400	3	73,580		902	113
Total.....	18	16			13	790,222	23	698,100	7	605,015	28	1,892	68
Average.....						60,786		30,352		86,574			
South Dakota:													
Elevators.....	105	29	9	\$1,814,589	80	9,584,116	88	11,922,155	19	3,206,000	120	11,749	98
Creameries and cheese factories.....	9	17	8	200,056	18	506,107	16	314,663	5	78,386	21	1,878	89
Fruit and produce.....	1						1	80,000	1	70,000	1	7	7
Stores.....	1		3	41,194	2	80,998					3	184	61
Miscellaneous.....	7	4	1		8	684,615	9	496,311	1	33,000	9	1,242	138
Total.....	123	53	18	2,055,839	108	10,855,836	112	12,813,129	26	3,387,396	154	15,060	98
Average.....				114,213		100,517		114,403		130,284			
Tennessee:													
Creameries and cheese factories.....	1	1			1	28,000	1	33,000			2	135	68
Fruit and produce.....	3	12	1	2,000	10	287,838	11	296,350	4	94,800	16	2,339	146
Cotton.....	5				2	31,000	3	34,000	1	3,500	5	293	59
Stores.....	2	9			1	3,000	9	178,000	7	203,000	11	1,821	166
Tobacco.....							1	180,000			1	20	20
Miscellaneous.....	1	11			2	14,100	7	98,400	3	115,000	14	1,492	107
Total.....	12	33	1	2,000	16	363,938	32	800,350	15	416,300	49	6,100	124
Average.....				2,000		22,746		25,011		27,753			

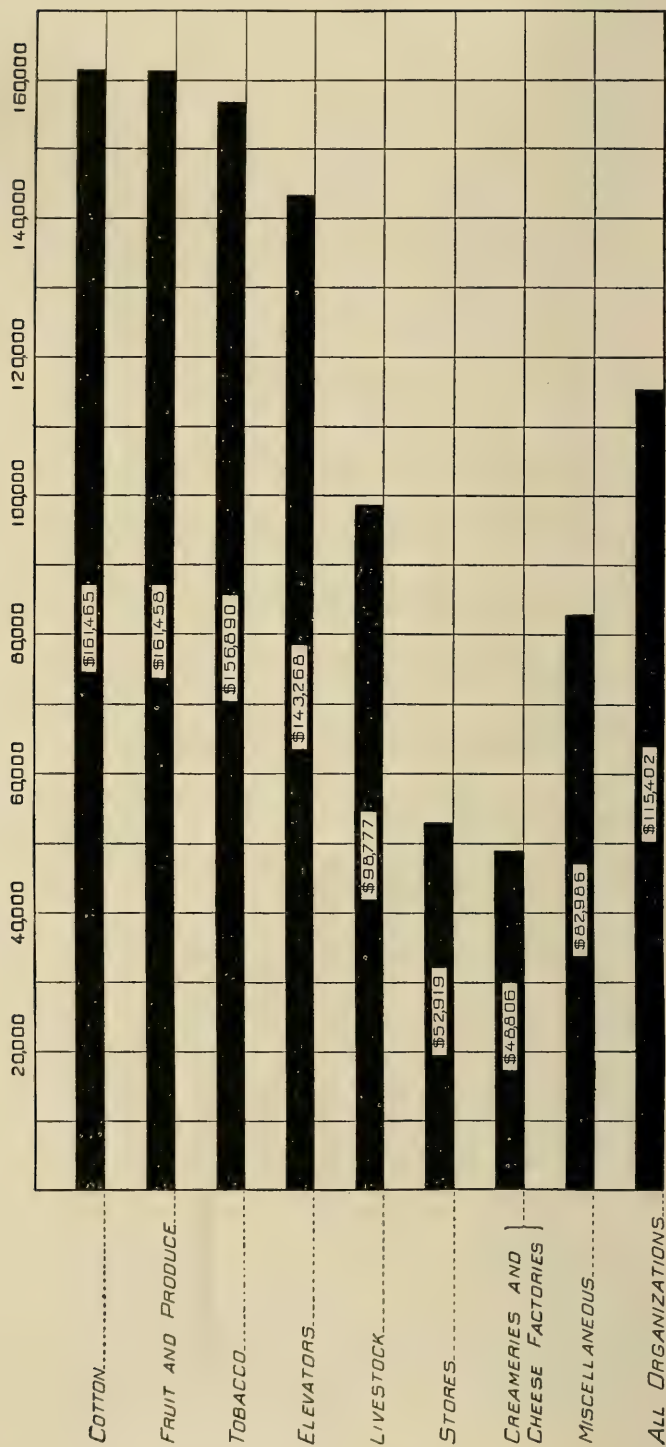
Texas:	Elevators.....	6	1	2	275,000	3	470,000	5	915,000	.....	.....	.....	5	525	105
	Creameries and cheese factories.....	5	2	2	37,000	4	182,004	6	237,929	2	30,500	.....	5	217	43
	Fruit and produce.....	8	23	2	2,600,000	14	2,582,104	13	719,700	2	21,200	.....	28	5,612	200
	Cotton.....	56	11	.....	.....	25	2,275,839	36	2,516,495	5	45,000	.....	60	6,713	112
	Miscellaneous.....	2	14	.....	.....	.....	.....	4	191,381	5	69,700	.....	14	1,715	123
Total.....		77	51	6	2,912,000	46	5,509,947	64	4,580,505	14	165,400	.....	112	14,782	132
Average.....		.....	.....	.....	485,333	.....	119,781	.....	71,570	.....	11,814	.....	.....	.....	.....
Utah:	Elevators.....	1	3	.....	.....	1	12,000	1	115,000	1	90,000	.....	4	193	48
	Creameries and cheese factories.....	5	4	.....	.....	5	229,723	7	266,709	1	18,000	.....	8	626	78
	Fruit and produce.....	6	3	3	55,903	8	1,008,439	3	835,893	.....	.....	.....	9	1,548	172
	Stores.....	.....	1	.....	.....	.....	.....	1	3,600	.....	.....	.....	1	457	457
	Miscellaneous.....	2	2	.....	.....	2	55,000	5	141,500	1	90,000	.....	5	916	183
Total.....		14	13	3	55,903	16	1,305,162	17	1,362,702	3	198,000	.....	27	3,740	139
Average.....		.....	.....	.....	18,634	.....	81,573	.....	80,159	.....	66,000	.....	.....	.....	.....
Vermont:	Creameries and cheese factories.....	10	12	14	564,940	15	688,472	5	252,221	2	111,000	.....	17	699	41
	Miscellaneous.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	150	150
Total.....		10	13	14	564,940	15	688,472	5	252,221	2	111,000	.....	18	849	47
Average.....		.....	.....	.....	40,353	.....	45,898	.....	50,444	.....	55,500	.....	.....	.....	.....
Virginia:	Creameries and cheese factories.....	7	1	1	10,000	4	105,500	4	153,000	.....	.....	.....	5	256	51
	Fruit and produce.....	4	8	4	4,195,000	7	5,816,000	5	46,400	2	52,000	.....	9	3,639	404
	Stores.....	.....	3	.....	.....	.....	.....	1	5,000	1	5,000	.....	3	158	53
	Tobacco.....	3	2	1	22,000	.....	.....	1	133,722	1	150,000	.....	5	402	80
	Live stock.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	1	45	45	
Total.....		2	24	.....	.....	4	14,100	7	27,687	6	29,600	.....	25	5,318	213
Average.....		16	39	6	4,227,000	15	5,935,600	18	365,809	10	236,600	.....	48	9,818	205
.....		.....	.....	.....	704,500	.....	395,707	.....	20,323	.....	23,660	.....	.....	.....	.....
Washington:	Elevators.....	37	11	5	1,400,000	32	5,215,431	36	6,021,978	7	1,448,000	.....	47	4,207	90
	Creameries and cheese factories.....	3	10	1	14,500	10	786,291	11	922,345	1	75,000	.....	13	1,233	95
	Fruit and produce.....	17	30	11	2,638,887	27	8,056,784	19	8,182,701	.....	.....	.....	48	13,774	287
	Stores.....	3	8	.....	.....	6	680,535	11	1,306,267	2	305,000	.....	12	11,492	958
	Miscellaneous.....	3	4	1	200,000	3	163,000	4	161,000	.....	.....	.....	5	417	83
Total.....		63	63	18	4,153,387	78	14,832,041	81	16,594,291	10	1,828,000	.....	125	31,123	249
Average.....		.....	.....	.....	230,744	.....	190,795	.....	204,868	.....	152,800	.....	.....	.....	.....

TABLE II.—Type of organization, volume of business, and number of members of organizations reporting, by States and kinds of business—Continued.

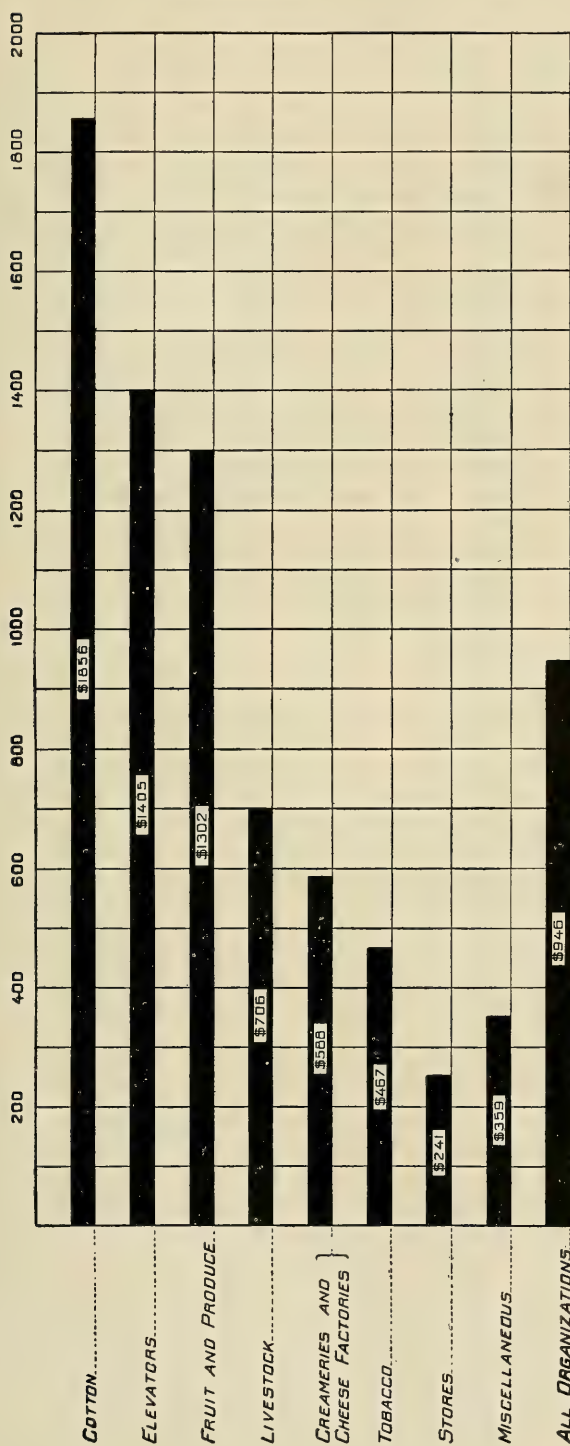
State.	Type of organization.		Volume of business.						Membership.		
			1912		1913		1914		1915		
	Stock company.	Co-operative.	Number reporting.	Volume.	Number reporting.	Volume.	Number reporting.	Volume.	Number reporting.	Volume.	Average.
West Virginia:											
	3	1									93
		1									150
		7	1	\$9,000	3	\$25,000			1	\$30,000	170
Total:	3	9	1		3	25,000	4	57,000	11	1,542	140
	Average.....					8,333		14,250			
Wisconsin:											
	13	6									122
		171				743,104	13	1,055,055	2	217,921	74
		12	216	10,132,421	100	7,655,547	16	1,046,000	265	19,726	82
		12	17	784,908	16	877,195			22	1,806	140
		7	5	90,600	13	507,161	3	110,000	27	3,781	156
		1	6		3	274,464	2	20,000	7	1,093	184
		6	5	162,000	8	426,320	13	404,282	15	2,700	89
		8									
	153	227	91	4,148,277	275	12,836,553	218	10,768,704	355	31,491	
Wyoming:											
	1	6									70
		1									35
		1									58
	2		2	440,000	5	302,500			8	559	12
			1	12,000	2	156,312	1	160,000	2	70	171
		1			1	40,000			1	685	87
		2			2	78,790					
	4	10	3	452,000	10	577,602	1	160,000	16	1,384	
United States:											
	1,074	496	960	130,555,221	913	132,665,430	180	26,182,831	1,471	149,618	
				186,911		145,307		145,460		102	
Total:											
	521	1,124	379	17,467,709	953	46,106,095	176	8,256,921	1,443	119,444	
				46,089		50,296		46,914		88	



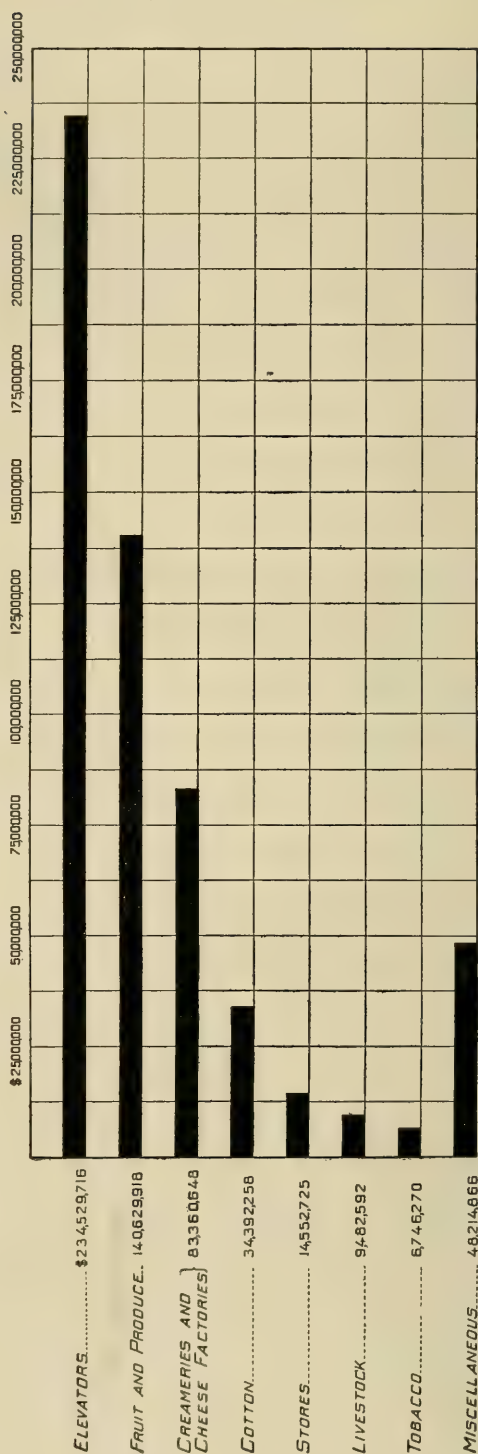
AVERAGE NUMBER OF MEMBERS FOR EACH CLASS OF ORGANIZATION.



AVERAGE BUSINESS PER ORGANIZATION BY CLASS.



AVERAGE BUSINESS PER MEMBER FOR EACH CLASS OF ORGANIZATION.



VOLUME OF BUSINESS OF ALL ORGANIZATIONS BY CLASSES.

Requests for information were sent out at various times as new names were added to the list, and in the case of a number of associations several requests were made before any reply was received. This work extended over the years 1914 and 1915; consequently the volume of business reported by the organizations is distributed over a number of years. A few reported their business for 1912 and a few for 1915, but most of the reports cover the years 1913 and 1914. Many of the associations reported the volume of business for more than one year, therefore there are some duplications. In order to get the average volume of business, the reports for the four years have all been taken into consideration. The total shown for each year must not be taken as the total volume of all associations for that year. A total of 889 associations reported their volume of business for 1912; 3,099 reported for 1913; 2,877 reported for 1914; and 534 reported for 1915. The average volume shown for the years 1912 and 1915 can not be taken as representative of the true average in every case because of the small proportions of the total number reporting for those years.

The last three columns of Table II show the number of each class of organization and the total number of organizations reporting their membership; the total membership and the average membership per association also is shown. (See also chart 4.) The average membership of all the organizations reporting is 122. Tobacco associations show the largest average, having 336; the miscellaneous associations, 231; stores, 220; live stock, 140; fruit and produce, 124; elevators, 102; cotton, 87; and creameries and cheese factories, 83. (See also chart 5.)

All of the organizations did not report on every point concerning which information was requested, but using the average of those reporting as a basis, estimates have been made of the annual volume of business and the membership of all organizations reporting. These estimates are shown in Table III, and are presented graphically in charts 6 and 7. It is estimated that the 5,424 organizations reporting have an annual volume of business of \$625,940,448 and a total membership of 661,728. In the matter of volume of business the elevators take the lead with an estimated total of \$234,529,716; next come fruit and produce associations with a total of \$140,629,918; creameries and cheese factories are third with \$83,360,648; then the miscellaneous marketing associations, \$48,214,866; cotton associations, \$34,392,258; stores, \$14,552,725; live stock shipping associations, \$9,482,592; and tobacco associations, \$6,746,270. (See also chart 8.)

TABLE III.—*Estimated volume of business and membership by kinds of organizations.*

Kind of organization.	Number of organizations.	Annual volume of business.		Membership.	
		Estimated total.	Average of organizations reporting.	Estimated total.	Average of organizations reporting.
Elevators.....	1,637	\$234,529,716	\$143,268	166,974	102
Creameries and cheese factories.....	1,708	83,360,648	48,806	141,786	83
Fruit and produce.....	871	140,629,918	161,458	108,004	124
Cotton.....	213	34,392,258	161,465	18,531	87
Stores.....	275	14,552,725	52,919	60,500	220
Tobacco.....	43	6,746,270	156,890	14,448	336
Live stock.....	96	9,482,592	98,777	13,440	140
Miscellaneous.....	581	48,214,866	82,986	134,211	231
Total.....	5,424	625,940,448	115,402	661,728	122

¹ Total volume of business and total membership obtained by multiplying average reported by total number.

FARMERS' GRAIN ELEVATORS AND WAREHOUSES.

Number and location.—The 1,637 grain elevators and warehouses that reported are distributed among 23 States, as shown in Table I. North Dakota reports 264, Minnesota 241, Iowa 228, Illinois 192, Nebraska 183, Kansas 153, and South Dakota 135. (See also Chart 9.) In other words, over 85 per cent of the elevators reporting are located in these seven States of the grain belt. In Oregon, Washington, Idaho, Utah, and Colorado practically all of the grain has been handled in sacks until recently; consequently the farmers in these States have operated warehouses instead of elevators. Terminal facilities are now being completed in the Pacific coast grain centers for handling grain in bulk, and many of the warehouse companies are preparing to construct elevators. When the practice of handling grain in bulk at the terminal markets becomes general the warehouses gradually will be replaced by elevators. One of the chief reasons for bringing about this change has been the high cost of grain sacks, the price of which has increased rapidly during the last two years.

It is estimated that there are a few hundred farmers' grain marketing organizations from which no reports have been received, but as the larger and more successful concerns appear to have been the most prompt in replying to the request for information, it is believed that the majority of those not replying are smaller organizations.

Plan of organization.—One thousand and seventy-four elevators and warehouses report being organized as capital stock companies, and 496 as cooperative companies. It must be borne in mind that those in the latter group are also for the most part organized with capital stock. The first class consists of those concerns which manage their business and distribute their profits according to the method commonly followed by stock companies. Companies which had

only a few members or which appeared to have most of the stock owned by one or a few individuals were excluded entirely. While 1,074 elevators do not distribute their profits in a cooperative manner, many of them have certain cooperative characteristics. In all of them the stock is distributed among a number of farmers; in some there is a limit to the number of shares one person may own; often there are regulations in regard to the transfer of stock; and many of these organizations adhere to the "one man one vote" principle. There are many cases where the stock is distributed among farmers, few holding more than one share. The main point on which these organizations fail to live up to cooperative principles is in the distribution of profits, since they fail to make use of the patronage dividend. In this connection the fact should be borne in mind that many of the States only recently have enacted cooperative laws, and in many instances the payment of dividends according to patronage has not been provided for. The elevators grouped in the cooperative class limit their stock dividends and distribute any further profits in the form of patronage dividends. Some of these pay patronage dividends to all of the patrons and some only to the patrons who are members. Often the nonmembers are paid at one-half the rate to members and some associations provide that the dividends to nonmembers shall be applied toward the purchase of a share of stock. The shares in these companies range from \$10 to \$100; in most cases the par value is from \$10 to \$25.

Business transacted.—As previously stated, the reports for the volume of business are not all for the same year. The average volume of business of those reporting was \$143,268; applying this average to all of the 1,637 elevators reporting, an annual business of \$234,529,716 is shown.

A large number of elevators carry side lines in addition to handling grain. Of the 1,637 elevators, 630, or 38 per cent of the total, handle fuel, indicating that the farmers' elevators have found this practice desirable. In most cases farmers themselves shovel the coal from the bins in order to reduce the handling charge to a minimum. Most of the coal is hauled by the farmers on the return trip from the elevator during the season when grain is being delivered. The largest number of elevators which handle fuel was reported from Iowa, this State having 99; North Dakota reported 94, Kansas 85, Nebraska 82, Minnesota 75, South Dakota 71, and Illinois 66.

The handling of live stock was reported by 132 elevators. Of this number 58, or a little over one-third, are located in Nebraska, showing how prevalent this practice is in that State; Iowa reported 20, South Dakota 13, and Minnesota 12 elevators handling live stock. Separate live stock shipping associations have sprung up in many

communities during the last few years, and if it were not for this fact more elevators might be handling this side line.

The handling of lumber was given as a side-line by 80 elevators. Of this number Iowa reported 33, Nebraska 13, and Illinois 10. The much smaller number of elevators handling lumber than fuel is accounted for largely by the fact that the carrying of lumber as a side line requires a greater outlay of capital and also takes up more of the manager's time than does the handling of fuel. It is not necessary to keep a very large supply of fuel on hand, while a considerable stock of lumber is required in order to have a supply of the various grades and kinds that are likely to be called for. One elevator reports having handled \$75,000 worth of lumber in one year, showing that in some cases lumber is an important item in the elevator business.

Kansas has 12 of the 28 elevators reporting the handling of fruit and produce. Of the 16 elevators handling merchandise, 6 are in Kansas and 3 in Montana; 640 elevators report the handling of miscellaneous products and supplies. In this class are included elevators handling such materials as binding twine, fence wire and posts, cement, oil, and miscellaneous items.

Members.—In Table II it is shown that 149,618 farmers compose the membership of 1,471 elevator and warehouse companies, an average of 102 for each company. Using this average as a basis, it is estimated that the 1,637 concerns covered by this report represent approximately 166,974 grain farmers, all of which directly benefit by the organizations of which they are members. A great many farmers who are not members but who ship their grain through the farmers' company derive benefits from it. Among such benefits would be the nonmember dividend where paid, and the advantage to all farmers in the community if the company in any way secures better prices for the farmers than were paid them before its organization. Such conditions as these exist in communities where, previous to the establishment of the farmers' company, no competition of any extent prevailed in the purchase of grain. From reports received as to the number of nonmembers who ship through farmers' companies, it is estimated that at least 125,000 who are not members market their grain through the 1,637 elevators covered in this survey. This number, plus the number of members, brings the total number of farmers doing business with these concerns to approximately 289,000.

New companies.—New companies are being formed constantly. No accurate record of the number has been kept from year to year but from such information as is available at this time it is estimated that several hundred companies were formed during 1914. Not all of these reached the point of doing business, because of trouble in securing capital or some other difficulty.

CREAMERIES AND CHEESE FACTORIES.

Number and location.—The 1,708 creameries and cheese factories which reported are distributed among 39 States as shown in Table I. Two-thirds of this number are located in the three States, Minnesota, Iowa, and Wisconsin, which States report 624, 301, and 204, respectively. New York has 75, Michigan 70, and the rest are widely distributed among 34 States. (See Chart 10.)

Plan of organization.—Classified according to the plan of organization as shown in Table II, there are 521 creameries and cheese factories which are operated on a capital stock basis and 1,124 which are cooperative. In many of the organizations operated on the capital stock company plan, the shares are distributed widely among the patrons and the plant is operated principally for their benefit. A much larger proportion of creameries and cheese factories are truly cooperative than is the case with farmers' elevators. This is due to the difference in the method of operation. The elevators pay cash for the grain as it is received, while most of the farmers' creameries make payments covering from 10 to 30 days' deliveries, deduct expenses and the necessary amounts for a reserve fund from the receipts of the sale of butter, and distribute the balance among the patrons according to the amount of raw material each has delivered. A creamery which operates on this basis is cooperative in the fullest sense of the word, even though it may never pay patronage dividends. A few of the companies pay the legal rate of interest on stock, charging this amount as an operating expense and deducting it from the returns.

Some of the creamery and cheese factory associations are formed on the nonstock plan. In such an organization the farmers have borrowed the necessary capital on a joint note signed by the members, this loan being repaid by assessments on each pound of butter fat or on each 100 pounds of milk delivered. An interesting situation is found at some of the creameries that have followed this method of financing the enterprise in that the debt has been paid but no one has anything to show that he has any interest in the creamery property, and as some of these associations are not incorporated it is a question as to who really owns the plant. Some of the organizations have found it desirable to buy in the capital stock of its members in the same manner as outlined above; this makes the creamery the property of all the patrons. Considerable difficulty would be experienced in liquidating one of these companies if the assets exceeded the liabilities, as ownership could be claimed by all patrons, past and present, who in any way had contributed to the business.

Business transacted.—The volume of business was reported for the years 1912 to 1915, inclusive, some organizations reporting for

each year; the average volume as reported was \$48,806. Using this average as a basis, the annual volume of business for the 1,708 creameries and cheese factories reporting is \$83,360,648. (See Table III.)

Only 58 of the creameries and cheese factories report handling products or supplies other than milk or cream. Five report handling fruit and produce, four report fuel, three live stock, two grain, and forty-four miscellaneous products. There is a striking contrast between creamery and cheese factory associations and elevator companies in this regard. Various reasons may be given in explanation of this difference. The creameries and cheese factories have a more uniform seasonal distribution of work than do the elevators, and the nature of the butter maker's or cheese maker's duties makes it inconvenient for him to attend to outside duties. It may not interfere very much with the work of the elevator manager for him to go out and assist a farmer in loading fuel, lumber, or other supplies, but it would be an unsatisfactory arrangement to have the butter maker divide his efforts between making butter and loading lumber or shoveling coal. The elevators are all on the railroad, are convenient for the unloading of supplies, and usually have ample warehouse and storage facilities. The creameries are often located at some distance from the railroad and usually lack the proper storage places for the handling of supplies.

Members.—The average membership reported was 83, or a total of 141,786 members in the 1,708 associations. As in the case of the elevators, many farmers are patrons of the creameries who do not hold memberships. Unlike patrons of many elevators, however, patrons of a large number of the creameries and cheese factories share in the benefits of the organization on the same basis as members, the farmer who delivers all of his product to the company being considered a member. There are cases where stock ownership forms the basis of membership, and others where the payment of a small fee is necessary to obtain the benefits of the association.

New companies.—The organization movement among dairy farmers is much older than that among the grain farmers; consequently, during the last few years the number of new farmers' creameries and cheese factories formed has been greatly exceeded by the number of farmers' grain elevators which have come into existence. The most rapid growth of the farmers' elevator movement has occurred during the last five years, while the height of the rapid organization period with creameries and cheese factories was reached about 1912.

A few central selling associations are being formed, and indications are that a great many of these will be created in the next few years by federating the present companies in a given territory, as the opinion prevails among the companies that better means must be provided

for selling the products now manufactured. Two of the central selling companies now operating are described in detail elsewhere in this report.

FRUIT AND PRODUCE MARKETING ASSOCIATIONS.

Number and location.—The 871 fruit and produce associations that reported have a much wider distribution throughout the country than any other class of cooperative enterprise, 42 States having one or more of these farmers' companies as shown in Table I. (See also Chart 11.) The leading States, and the number reporting from each, are California 124, Arkansas 63, Florida 55, Washington 52, Oregon 40, Louisiana 34, Missouri 34, New York 32 and Texas 31. In California and Florida organizations of citrus-fruit growers are the leading types; in the North Pacific States the apple growers' organizations predominate, and the organizations vary in the other regions of the country according to the principal kinds of fruit and produce raised in commercial quantities.

Plan of organization.—Of the fruit and produce associations, 307 reported operating on the capital stock company plan while 504 reported the cooperative method. Thus compared with elevators, a considerably larger proportion of the fruit and produce companies follow the cooperative method, while the proportion is somewhat smaller than in the case of creameries and cheese factories.

There is a general trend among cooperative fruit and vegetable marketing concerns toward centralized selling and unity of action in matters of mutual interest other than selling. This is accomplished by the federation of small local assembling associations into district organizations; these in turn operate through a central selling agency. In some cases the district or local associations federate for gathering crop and market information and for accomplishing other work which is impracticable for individual associations, but each retains its sales machinery and sales policy. The central sales policy is in operation among the citrus growers of Florida and California and the walnut and almond growers of California, and has from time to time gained and lost in favor among associations in the Pacific Northwest. The plan of federation for gathering information and perfecting better distribution has been used by numerous cooperative and independent companies in vegetable districts in handling unusually heavy crops.

A history of the cooperative movement in many of the fruit and produce districts would show numerous experiments and a rise and fall in the support of the organization from one year to another. Practically all new districts pass through the same general experience as that through which the older organizations passed; consequently, the most successful cooperative fruit and vegetable marketing concerns are usually found in districts where these associations



FIG. 1.—PACKING HOUSE—COOPERATIVE CITRUS FRUIT MARKETING ORGANIZATION.

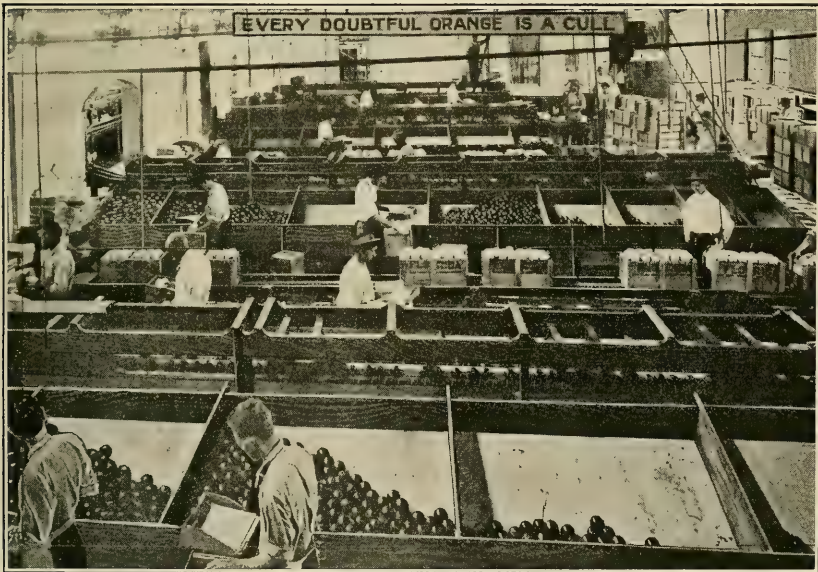


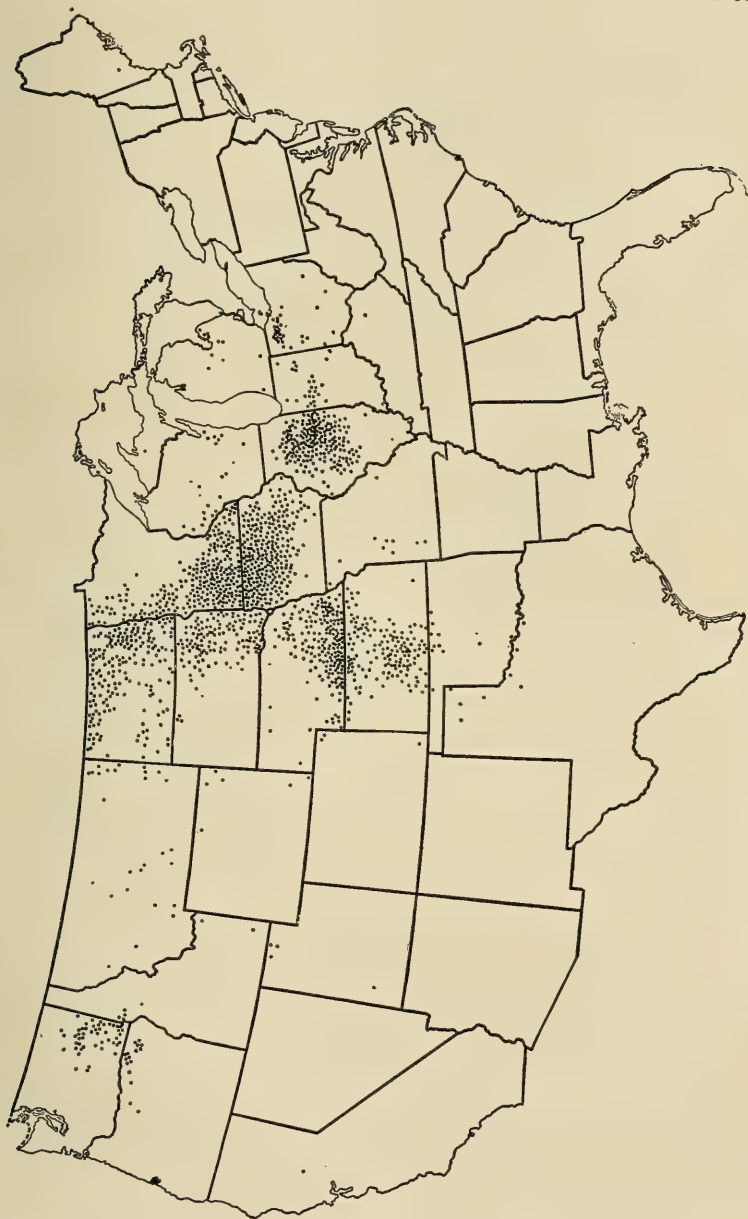
FIG. 2.—INTERIOR VIEW OF PACKING HOUSE—COOPERATIVE CITRUS FRUIT MARKETING ORGANIZATION.



FIG. 1.—FARMERS' COTTON GIN.



FIG. 2.—FARMERS' COOPERATIVE STORE.



LOCATION OF COOPERATIVE GRAIN ELEVATORS AND WAREHOUSES REPORTING.



LOCATION OF COOPERATIVE CREAMERIES AND CHEESE FACTORIES REPORTING.



LOCATION OF COOPERATIVE FRUIT AND PRODUCE ORGANIZATIONS REPORTING.

are not of comparatively recent origin. There are a few exceptions, such as several of the district organizations in the Pacific Northwest which have made rapid progress during the short periods in which they have been in existence.

Cooperation in the marketing and distributing of fruit and vegetable products is found to exist in its greatest strength in sections which are far removed from the consuming centers of the country. In other words, necessity will bring about cooperative organization in order to overcome such handicaps as a long distance from market, the perishable nature of the product which requires skill in marketing and distributing, and lack of sufficient buyers in the fields to purchase the entire crop regularly for cash.

Business transacted.—The average annual volume of business reported is \$161,458. Since the total number reporting was 871, this amount gives an estimated total annual volume of business of \$140,629,918. In determining this sum care was taken to exclude the figures for the large central organizations, in order to have a representative average, for, if several of these large enterprises were included, the increase in the average would lead to considerable error in estimating the total volume of business. The volume of business of the central organization is the sum total of the business of the local organizations of which it consists, so if these as well as the centrals were included, there would be a duplication.

Box shooks, paper, nails, spray materials, and general growers' supplies are handled by practically all of these organizations. As most of the companies finance the members in purchasing supplies, they have found it less difficult to handle the articles which are needed in large quantities than to depend on various outside sources. Prices, quality, and supply fluctuate to such an extent that many growers have been seriously handicapped in securing the desired articles at the proper time from the miscellaneous sources available. The handling of supplies has been found a profitable business to both the company and the grower and when once begun the practice is seldom discontinued.

Products and supplies are handled by 190 of the fruit and produce associations reporting. Forty-five are engaged in canning; the handling of fertilizers is reported by 11; grain is handled by 5, and the same number report fuel; 4 report merchandise; 2 ship live stock; and 118 handle a number of products classed as miscellaneous.

Members.—The average number of members reported by 778 fruit and produce associations is 124, and the estimated total membership of 875 associations reporting is 108,004.

Usually producers must take out a membership in order to ship their products through these organizations. Membership fees range

from \$5 to \$100, and the memberships are nontransferable in practically all cases. In a few instances the mere signing of contracts to deliver all of certain products to the association for sale, constitutes membership. These contracts are continuous and the grower's right to cancel them is restricted to certain periods of each year.

New companies.—Cooperation among fruit and produce associations is passing through a stage of experimental development in most sections of the country, and is developing rapidly in many of the truck and newer fruit producing sections of the United States, especially in the South. New concerns are launched each year. Although some of them endure but a short time, indications point toward a rapid development in the next few years in cooperative methods of handling perishable products in the producing sections of the country.

Fruit and vegetable canneries.—Forty-five of the companies which are classed as fruit and produce associations in this study operate canneries. Practically all of these organizations are engaged primarily in canning fruit and vegetable products, but most of them ship products in the fresh state when markets are considered good. The largest number of farmers' canneries are found in Indiana and the North Pacific States; the business ranges from \$10,000 to \$1,500,000 each per year. Various small berries, larger fruits, and vegetables are canned. A few of these concerns operate vinegar plants and evaporators in conjunction with the canning business.

About \$3,500,000 was received for canned and dried fruits and vegetables by cooperative canning plants in 1914. This is a comparatively small amount, since the value of this business as a whole in the United States for 1914 was in excess of \$158,000,000. Few farmers' canneries have succeeded. In one State alone 80 canneries which were organized during a period of 10 years by local farmers are now out of existence. None attained any degree of success.

COTTON ORGANIZATIONS.

Reports were received from 213 cotton associations distributed among 14 States. Over one-half of them are located in the States of Texas and Georgia, the former reporting 71 and the latter 44. Alabama reported 19, Arkansas 15, South Carolina 14, Oklahoma 13, Mississippi 11, and North Carolina 10; and the remainder are scattered over the other cotton-producing States of the South. Practically all are cotton warehousing associations. Comparing the number of grain elevators and the number of cotton associations, it is evident that the cotton growers of the South are not nearly as well organized as the grain growers of the North Central States.

The capital stock company plan of operation seems to be the favorite plan for the cotton associations, 156 reporting this form and 40 reporting the cooperative form. The cotton organizations resemble the grain elevators in this respect.

The average volume of business of the organizations reporting on this point was \$161,465. This makes a total for the 213 organizations of \$34,392,045.

One hundred and forty-five associations reported an average of 87 members, which number gives a total of 18,531 members for the entire 213 associations reporting.

The handling of other products and supplies was reported by 25 associations. Of this number, 7 handle fertilizers, 3 grain, 1 fuel, and 14 miscellaneous products.

COOPERATIVE STORES.

The 275 stores that reported are well distributed over 35 States. Kansas has 36, Wisconsin 32, Minnesota 30, North Carolina 17, and Iowa 14. (See Table I.) It is probable that there are a number of cooperative stores in existence whose names have not been secured, for it was found that the agencies that furnished the names were more likely to overlook cooperative stores than any of the organizations engaged more directly in the marketing of agricultural products.

More stores reported as operating under the cooperative plan than under the stock company plan of doing business; 163 reported the former and 90 the latter plan.

The average volume of business reported was \$52,919, making a total of \$14,552,725 for the 275 stores which replied. The average number of members reported by the stores was 220 per association, a total of 60,500 for the 275 stores. Of the 275 stores, 97 reported handling side lines; 15 reported fruit and produce, 6 of these being in Kansas; 9 reported grain; 8 reported fuel; 6 ship cream, 4 of these being in Kansas; 5 handle fertilizers; 4 cotton; 3 lumber; 1 live stock; and 46 handle miscellaneous products and supplies.

TOBACCO ASSOCIATIONS.

The State of Kentucky is the home of 21 of the 43 tobacco associations reporting. There were 7 in Ohio, 5 in North Carolina, and 5 in Virginia. Of the 39 tobacco associations concerning which information on the type of organization was obtained, 32 were placed in the capital stock company class and the remaining 7 in the cooperative. The average volume of business of those reporting on this point was \$156,890, making a total annual volume of \$6,746,270 for the 43 organizations reporting. The average membership reported by tobacco associations is larger than for the other kinds of business, being 336, or a total of 14,448 members in the 43 associations. The

activities of these organizations are restricted largely to the handling of tobacco. Only two reported the handling of any other product; one reported fertilizers and the other miscellaneous products.

LIVE STOCK ASSOCIATIONS.

Farmers' associations for the marketing of live stock are of recent origin, most of them having developed during the last few years. The form of organization is more or less informal. As most of them do not own any property or need any great amount of capital, they are frequently not incorporated under the State laws. On this account there are undoubtedly a number of live-stock shipping associations of which the names have not been reported, and also a large number that have failed to reply to the request for information. In all, 96 of this class reported; 30 are in Minnesota, 25 in Nebraska, 20 in Iowa, and the remaining 21 are distributed among 11 States.

The method commonly used by these organizations is to ship the stock and, after the returns of the sale are received, to make deductions to cover the necessary expenses, including the manager's commission, and to pay the remainder to the farmers. It is therefore not strange that 64 of the associations reported the cooperative form of organization and that only 17 followed the stock company method of doing business.

The average volume of business reported is \$98,777, or a total of \$9,482,592 for the 96 associations. The average number of members is 140, or a total of 13,440 members.

Side lines are handled by 35 of these live stock associations. Fuel is reported by 9, lumber by 5, merchandise by 1, produce by 1, cream by 1, and miscellaneous products and supplies by 18.

MISCELLANEOUS ORGANIZATIONS.

Of the organizations reporting, 581 were classed as miscellaneous. (See Table I.) Some of these handle only one product, while others market a variety of products. When only a few associations were handling a certain product, they were placed in the miscellaneous class, as were the organizations whose kind of business could not be ascertained accurately. The geographical distribution of the miscellaneous organizations is fairly uniform, 47 of the States being represented. The leading States in point of number are Nebraska 46, Kansas 39, Maine 39, California 34, Iowa 31, North Carolina 28, Washington 28, Minnesota 27, Idaho 26, and Illinois 24.

The miscellaneous organizations show a larger number reporting the cooperative plan than the stock plan, there being 313 of the former and 219 of the latter. The average annual volume of business

of this class of organizations is \$82,986, making the total for the 581 organizations \$48,214,866.

Four hundred and ninety-four organizations reported an average membership of 231; at this rate the total membership in the 581 associations is 134,211.

Some of the associations which have been included in the miscellaneous class failed to report the products and supplies handled. The others reported handling a variety of products. Fruit and produce are handled by 68, fuel by 43, lumber by 42, fertilizers by 42, grain by 22, nuts by 19, cream by 13, cotton by 12, live stock by 7, merchandise by 5, tobacco by 3, and miscellaneous products and supplies, other than those mentioned, are handled by 339.

COOPERATION IN REPRESENTATIVE STATES.

In order to give a clear presentation of the status of organization in the various parts of the United States, brief statements showing the results of the survey in different States are included. By selecting States representative of the different sections of the country, the varying conditions surrounding the organization of the farmers are shown. Several of the States of the North Central group have been included because in this section cooperation among farmers is more general than in any other part of the country. States have been selected also to show the extent of agricultural organization among the fruit growers of the West, the farmers of the South, of the tobacco belt, the truck-growing regions, and the older farming regions of the North Atlantic States.

MINNESOTA.

Minnesota leads the States in the number of cooperative organizations of farmers. Of the 5,424 organizations in the United States which are included in this survey, 980, or 18 per cent of the total, are located in Minnesota. The prominence of Minnesota's place in the matter of marketing organizations among the farmers is largely due to its importance as a dairy State. Cooperative creameries and cheese factories make up about 63 per cent of Minnesota's total, while the elevator companies comprise about 25 per cent. The remaining 12 per cent include live-stock shipping associations, fruit and produce associations, and a few miscellaneous organizations.

The creameries and cheese factories of Minnesota show the possibilities of such farmers' organizations. Over 600 of the 850 creameries of the State are owned by the farmers. Table II shows that most of these creameries are cooperative in character. Nearly all of the farmers' associations in Minnesota which report the stock-company plan of organization are farmers' elevators; the other classes adhere much more closely to cooperative principles in the method of conducting their business.

An estimate of the volume of business transacted by the farmers' marketing organizations of Minnesota can be made by using the figures reported by a large proportion of the associations as a basis. The total annual volume exceeds \$50,000,000. The 980 organizations reporting have about 90,000 members, which gives an indication of the extent of organization among farmers for manufacturing and marketing purposes in this State.

IOWA.

As Iowa is represented by 505 farmers' marketing organizations, it is second to Minnesota in number reporting. Conditions in Iowa and Minnesota are very similar, and the farmers' organizations have followed the same lines in both States. The two leading forms of organization in Iowa are elevators and creameries, as these two classes make up over 85 per cent of the total reporting. Iowa falls behind Minnesota in total number of organizations largely because of its smaller number of creamery and cheese-factory associations, Iowa reporting 204 and Minnesota 624 organizations of this character.

WISCONSIN.

Wisconsin ranks third in the number of organizations reporting. Conditions in this State differ somewhat from those in Minnesota and Iowa. The latter are important grain-raising States and have a number of farmers' elevators, while in Wisconsin, where grain is not grown on such an extensive scale, there are comparatively few farmers' elevators. Wisconsin is an important dairy State; therefore 75 per cent of the companies reporting are creameries or cheese factories. In Minnesota and Iowa nearly all of the dairy organizations are creameries, while in Wisconsin there are a large number of cheese factories as well. The other forms of organization found in Wisconsin are of the same nature as those found in Minnesota and Iowa.

KANSAS.

Kansas is another member of the group of States where farmers' organizations are the most numerous. It is an important grain State; consequently over 60 per cent of the associations reporting from this State are farmers' elevator companies. Kansas may be contrasted with Wisconsin in the matter of farmers' associations; the former has a large number of grain elevators and only a few creamery or cheese-factory organizations, while the situation is reversed in the latter State.

CALIFORNIA.

Conditions surrounding the organization of farmers in California are decidedly different from those in the North Central States. California is one of the leading fruit-growing States, and as the fruit

grower has found it profitable to organize for the marketing of his products, it is not strange that over 60 per cent of the organizations which reported from this State belong to the fruit and produce class. The others consist of creameries and cheese factories, stores, olive and nut associations, and various miscellaneous farmers' marketing enterprises.

Cooperation in this State is noted especially for the central organizations made up of local units which are found among the citrus, walnut, almond, raisin, and apple growers. The elevators and creameries of the North Central States for the most part have been content with the method of allowing each local concern to look after the marketing of its own products independent of neighboring associations of the same character. The fruit growers of California have found it advantageous to unite their local associations into central selling bodies. It must not be inferred that this is the only State where such central organizations are found, for there are a number of examples of such centralization throughout the United States, but the success of this form of endeavor has been particularly notable in California.

THE NORTH PACIFIC STATES.

The four Pacific Northwestern States—Oregon, Washington, Idaho, and Montana—may be grouped together in considering farmers' marketing activities. Conditions are similar in the four States with reference to organization and some of the lines of activity extend to all of the States in the group. Of the 329 organizations which reported from these four States, about 35 per cent are fruit and produce associations, 30 per cent are grain elevators or warehouses, 15 per cent are creameries or cheese factories, 7 per cent are stores, and 13 per cent are classed as miscellaneous associations.

The central selling organizations found in these States among the apple growers are the most notable. For the last five years various movements have been set on foot to make the fruit growers' associations in these States more effective. These movements have resulted in the rise and fall of numerous central selling or other associations, and a continual changing of affiliations and policies on the part of local associations. In this region are a number of very successful canneries which have been established to take care of fruit and vegetable products which can not be marketed to advantage in the fresh state. Not all of the canneries established have been successful, for a large number of failures were reported.

TEXAS.

The State of Texas may be considered by itself because of the conditions here represented. Over 50 per cent of the organizations reporting from this State are cotton associations and about 20 per cent

are fruit and produce associations. In the remaining number are a few creameries, a few grain elevators, and some miscellaneous organizations.

FLORIDA.

Florida, like California, is interesting because it is represented largely by organizations for the marketing of perishable products, such as citrus fruits. About 80 per cent of the organizations reporting from this State belong to the fruit and produce class, which indicates the importance of this form of organization in the State. The other associations in the State belong principally to the miscellaneous class.

NORTH CAROLINA, SOUTH CAROLINA, AND GEORGIA.

The States of North Carolina, South Carolina, and Georgia have been placed in one group, since they are representative of that section of the United States. Of the total number of organizations which reported from these three States, about 41 per cent handle cotton in the capacity of warehousemen, this form of organization being especially common in Georgia; about 12 per cent handle fruit and produce; about 12 per cent are stores; over 25 per cent fall in the miscellaneous class; and the remainder consists of a few creameries and tobacco associations and one live-stock association.

KENTUCKY.

From the standpoint of organization of producers for marketing purposes, the State of Kentucky is interesting because of its tobacco growers' associations. Almost one-half of the tobacco associations from which reports have been received are located in this State. Kentucky reported 66 organizations, and of this number 21 are tobacco associations, 15 are fruit and produce associations, 17 are listed as miscellaneous, 6 are stores, 6 creameries or cheese factories, and 1 a grain elevator company.

VIRGINIA, MARYLAND, AND DELAWARE.

The States of Virginia, Maryland, and Delaware reported a total of 82 marketing associations. Of this number, 39 are miscellaneous organizations, 22 are fruit and produce associations, 12 are creamery or cheese factory associations, 5 handle tobacco, and 1 handles live stock. These States are in a truck and fruit growing section, and this fact accounts for the organizations which handle fruit and produce. There are some good examples of central marketing organizations among the truck growers in this section of the United States.

NEW YORK.

One hundred and twenty-four organizations in the State of New York reported. About 60 per cent of this number are creamery and cheese factory associations, about 25 per cent handle fruit and produce, and the rest is made up of a few cooperative stores and miscellaneous organizations.

THE NEW ENGLAND STATES.

The New England group of States reported a total of 157 marketing organizations. Of this number 61 are creameries, 49 are miscellaneous, 27 handle fruit and produce, 19 are stores, and 1 is a grain elevator.

REPRESENTATIVE TYPES OF COOPERATIVE ORGANIZATIONS.

Requests for more detailed information were sent out to some of the larger cooperative associations and also to organizations typical of a certain class or illustrative of some special development along cooperative lines. The data secured from the replies to these requests furnished the basis for the brief statements which follow. This information is included in order to show what is being accomplished by some of the cooperative organizations.

These particular organizations were selected because more detailed information as to their methods of operation was available for them than for other representative cooperative associations. A great many cooperative companies besides those mentioned here are worthy of study and special consideration by students of cooperation and by those who are contemplating the formation of new cooperative enterprises.

THE CALIFORNIA FRUIT GROWERS' EXCHANGE.

The California Fruit Growers' Exchange is a cooperative organization of citrus growers through which over 60 per cent of the citrus fruit shipped out of California is distributed. The annual report of the general manager for the year ending August 31, 1916, shows that the exchange shipped 24,024 cars of oranges and grapefruit and 5,799 cars of lemons during the year. The amount returned to the growers for this fruit exceeded \$27,000,000. At present over 8,000 growers are members of the exchange.

The growers are organized into local associations, which in turn are members of district exchanges, and these are united in the central exchange. The local associations are made up of the growers in a community, the membership ranging from 40 to 200. The fruit is assembled and prepared for shipment by the local associations. The district exchanges order cars for the local associations in their respective districts, keep records of the cars shipped, receive the returns from the central exchange and distribute the proceeds to the local associations, and keep the local associations informed with regard to matters pertaining to the industry. The central exchange provides the facilities for the distribution and marketing of the fruit of its members.

The California Fruit Growers' Exchange has agencies in the principal markets of the United States and Canada which represent the exchange and its members exclusively. In this way the exchange is

able to exercise careful supervision over the distribution of the products of its members and also to secure daily information with regard to conditions in the various markets. The exchange has a number of departments which undertake different lines of work. Thus, the sales department looks after the marketing of the fruit; the traffic department takes up matters relative to transportation; the field department assists in the standardization of the fruit and its preparation for market, and also in securing new members; the advertising department handles the work of advertising the products of the members; and the legal department keeps the exchange and its members informed with regard to legislation affecting the industry.

Supplies needed by the growers are purchased through a separate organization known as the Fruit Growers' Supply Co. This company reports handling a business of over \$4,000,000 during the year ending August 31, 1916. The supplies purchased by the members through this organization include box shooks, labels, tissue wraps, spray materials, fertilizers, and other packing-house and orchard supplies.

CALIFORNIA ALMOND GROWERS' EXCHANGE.

Unsatisfactory conditions surrounding the marketing of almonds led to the organization of the California Almond Growers' Exchange. The first almond growers' association was organized almost 20 years ago and similar organizations were formed from time to time. As these organizations found that they could not accomplish a great deal individually, it was decided to unite, and as a result the California Almond Growers' Exchange was established in 1910. When first organized the exchange consisted of 11 associations made up of about 230 growers, while at the present time there are 18 associations with a total membership of about 1,000.

The purpose of the exchange is to secure a fair price for the product of the member associations at as low a cost of marketing as possible. Through further centralization, duplication of sales machinery is avoided, more efficient distribution can be secured, and a general control of the product makes advertising on an extensive scale possible.

The California Almond Growers' Exchange consists of a number of local nonstock associations with a membership fee ranging from \$1 to \$2.50. The local associations are formed in communities where sufficient almonds are grown to make this advisable, and the associations thus formed affiliate with the central exchange. By special arrangements, growers in districts where there are no local associations may market through the exchange. A contract date is set after which no growers' tonnage will be accepted for sale. In this way a fairly accurate estimate of the prospective crop is secured which enables the sales department of the exchange to make arrangements for placing the crop.

Pools are maintained for each variety of fancy grade and the expenses of each pool are kept separate and charged to the almonds in that pool. The almonds that are not of the fancy grade are sold separately. Sales are made over a large part of the United States and as many as 600 wholesale dealers have handled the organization's output in one season. A nut-shelling plant has been erected, and it is planned to develop the eastern demand for shelled almonds. The present annual volume of business is about \$750,000, which will be increased within the next few years because of the large acreage planted to this crop which as yet is not in bearing.

THE DELTA CREAMERY CO., CALIFORNIA.

The Delta Creamery Co. was formed in 1910. Its membership is composed of dairymen and the business is operated for their mutual benefit. The returns from products handled by the company have been much more satisfactory than those received when the members marketed them individually.

The creamery has established a wholesale house in San Diego and at present about one-third of its output is marketed through this outlet with good results. It is planned to extend this method of selling so that the entire output can be sold in this way. The manager states that he believes the creamery owes its success in a large measure to its efficient employees and to the businesslike methods used in conducting the operations.

THE FLORIDA CITRUS EXCHANGE.

The Florida Citrus Exchange is a cooperative nonstock association which was formed on account of unsatisfactory conditions surrounding the marketing of the citrus fruit of Florida. Before this organization was formed each grower attended to the marketing of his own fruit and, as a consequence, proper supervision was lacking and sufficient attention was not given to grading and packing. Most of the packing was done in sheds, barns, and similar places, and little attention was given to the appearance of the fruit. During a period of six years a number of packing houses were built, and at present the Florida Citrus Exchange with its allied membership has about \$600,000 invested in such plants. An idea of the growth of the exchange is obtained from the statement that about 700,000 boxes of fruit were handled during its second year, while in 1915 it handled over 2,000,000 boxes. At first the loss on account of decay was large, but because of improved methods this loss has been greatly reduced, until at the present time it is comparatively small.

The exchange has been instrumental in securing new markets for Florida fruit. In the early days of the organization fruit was shipped to but 18 or 20 markets, while at the present time there are approximately 135 agencies throughout the United States and Canada which

handle the output. During the last four years \$250,000 has been spent in advertising the brands of the exchange. It is considered that this money has been well spent, as a reputation has been built up by proper grading and standardization which has been brought to the attention of many dealers and consumers, thus increasing the demand and resulting in greater consumption and better distribution.

The Florida Citrus Exchange consists of four divisions: First, the individual growers; second, the local associations made up of individual growers; third, the subexchanges made up of local associations; fourth, the central exchange made up of the subexchanges. The growers are the producers and the owners of the entire business. The local associations look after the picking, hauling, packing, and loading of the fruit belonging to its members. The subexchanges act as forwarding agents for the associations. The central exchange takes care of the selling, collecting, advertising, and kindred matters.

FARMERS' UNION OF MAINE.

The Farmers' Union of Maine was organized in 1912 as a result of a movement started by the Bureau of Markets and Supplies of the State Agricultural Department. A number of local associations were formed, which in turn formed a central organization called the Farmers' Union of Maine. At present there are over 70 local unions, every county in the State being represented by one or more unions. A local union becomes affiliated with the central organization by the purchase of five shares of stock at \$10 each.

The local unions began the shipping of potatoes in 1912 and shipped about 250 carloads during that season. Early in 1915 the union secured a stall in the Boston and Maine Railroad produce house in Boston and placed a man in charge. A total business of \$250,000 through this house is reported for the year 1915.

There was a demand among the farmers for supplies such as grain, flour, and feed, and the manager of the union succeeded in organizing the Farmers' Union Grain and Supply Co., which contracted with a private wholesale concern to handle supplies for the union. This company did a business of \$250,000 during last year. In the fall of 1915 the local unions voted to buy the private wholesale house, each local giving its note for \$500. It is estimated that the savings will pay the interest and retire the notes in about five years.

The Farmers' Union has effected a saving to the farmers in the matter of contracting for fertilizers. It had been customary for the farmers to purchase a large amount of these on credit, which meant the payment of considerably more than the cost price. The union was able to make a contract at a lower price than individual farmers were paying, and this new price was instrumental in reducing the cost to all the farmers.

The local unions have erected 23 warehouses or shipping houses, 25 grain stores, 3 grocery stores, and a gristmill. A wholesale grocery house and a flour mill are under consideration. The gross business during 1912-13 was \$324,000 and in 1914-15 it was \$800,000, an indication of the rapid growth of the business.

**THE LITCHFIELD DAIRY ASSOCIATION AND THE LIVE STOCK SHIPPING ASSOCIATION,
MICHIGAN.**

During the winter of 1910-11 the patrons of the local creamery at Litchfield, Mich., became dissatisfied with the prices paid them for butter fat. As a result the farmers purchased the creamery, and it has been conducted on the cooperative plan since that time. The annual volume of business has increased from 125,000 pounds of butter to 600,000 pounds. The creamery has been very successful and now has approximately 600 patrons, to whose cooperation, the manager states, the success of this enterprise is largely due. Other factors which have contributed to its success are good markets for its output, modern equipment, and efficient management.

Encouraged by the success of the creamery, the Live Stock Shipping Association was organized as a separate company by practically the same farmers who are interested in the creamery. The manager of the creamery is also manager of the Live Stock Shipping Association, and the business of both enterprises is handled from the same office. Members ship their stock on regular shipping days to the terminal markets in carload lots. Returns, less actual cost of handling and a small reserve fund, are prorated to each member. All stock shipped is marked and sold according to grade. This association is one of the earliest live-stock shipping associations and one of the most successful.

MINNESOTA COOPERATIVE DAIRIES ASSOCIATION.

The Minnesota Cooperative Dairies Association was organized in the summer of 1907 to bring about better marketing conditions among Minnesota creameries. It is a capital stock organization, and the shares are held by a number of cooperative creameries. In 1908 the association appointed an agent in Chicago to handle the butter consigned, and in 1909 similar arrangements were made with agents in New York and Philadelphia. As the agents appointed were regular butter dealers in these markets, this method of marketing did not differ materially from the method commonly employed.

It was the original plan of the association to have its own butter houses at the principal markets and to sell the output of the member creameries through them. In accordance with these plans a distributing office was opened in New York in the summer of 1915. On account of the short time this venture has been in operation it is not possible to say how successful or far-reaching the results will be.

THE OZARK FRUIT GROWERS' ASSOCIATION, MISSOURI AND ARKANSAS.

The Ozark Fruit Growers' Association is found in southern Missouri and northern Arkansas. The principal products marketed are strawberries and peaches. The organization consists of a central association which markets the fruit of a number of local associations affiliated with it. The secretary reports that there are 500 members, that the capital stock is \$2,000, divided into shares of \$1 each, no member owning more than 10 shares. Several hundred carloads of strawberries and peaches are marketed annually. The total business transacted in 1915 amounted to approximately \$600,000.

This association has been successful in standardizing its products and making its brand known to the trade. A new venture recently undertaken is the use of various trade papers in advising the trade generally of the association's output through advertisements carried during the marketing season. Marketing conditions and returns to growers have been much more satisfactory since the creation of this sales agency. As in the case of most successful fruit associations, better distribution has been obtained, together with a standardization of output and sales methods.

TILLAMOOK COUNTY CREAMERY ASSOCIATION, OREGON.

Previous to 1904 both the private and cooperative cheese factories of Tillamook County marketed their output individually by shipping to Portland dealers. This method was unsatisfactory because there was not a proper distribution, and as a result the dealers took advantage of the gluts in the market during the season of heavy production. In 1903 the Tillamook factory adopted the plan of distributing the output among several cities, according to demand. This venture was so successful that several plants appointed a sales manager to handle their output in a similar manner. The success of these plants was an impetus to cooperation, and gradually most of the private factories were taken over by the farmers.

In 1909 nine of the farmers' cheese factories organized the Tillamook County Creamery Association. The association engaged an inspector whose duties included general supervision over the cheese making, regular visits to each factory, and the giving of suggestions and lending of assistance where needed. This proved to be a wise move, as it has made the factories more efficient and has resulted in a product of better quality and greater uniformity. The association has a trade-mark for all cheese which measures up to the association standard when inspected.

The factories also cooperate in having a secretary-salesman who at the present time keeps the books and looks after the marketing of the product from 20 of the 23 factories in the county. The secretary receives frequent reports from the inspector and from the cheese

makers and is therefore at all times in a position to know the amount of cheese to be sold. He keeps in touch with the dealers and also with the eastern markets. The arrangements made with the dealers call for prompt payments, which enable the factories to pay their patrons regularly, and this is considered an important factor in the success of the venture. It is stated that it is not an uncommon thing for the sales to average over \$3,000 a day in periods of high production. The business of the federation for 1914 amounted to approximately \$568,000.

THE EASTERN SHORE OF VIRGINIA PRODUCE EXCHANGE, VIRGINIA.

The Eastern Shore of Virginia Produce Exchange was organized in 1900 for the purpose of marketing the products of the farmers living in the two counties that form the Virginia part of the peninsula between Chesapeake Bay and the Atlantic Ocean. This is a truck-farming district; the leading crops are Irish and sweet potatoes, strawberries, cabbages, and onions. The exchange markets the products of approximately 3,000 farmers, or about two-thirds of the total output of the territory in which it operates. The annual business includes the sale of 8,000 to 10,000 carloads of Irish potatoes, 2,500 to 3,000 carloads of sweet potatoes, and from 100 to 300 cars each of strawberries, onions, and cabbages. The total annual volume of business is from 5 to 6 million dollars. The exchange deals with over 1,300 wholesale buyers, distributed among about 500 cities in about 40 States and Provinces.

The right to sell produce through the exchange can be secured by becoming a stockholder, by being a tenant of a stockholder, or by purchasing a "shipping privilege," which costs \$1. The exchange has a central office, but there are a number of shipping points, as the territory is divided into 35 local divisions and each division has from one to four loading stations. Each local division elects a stockholder as a director for the general board of directors. The board of directors has supervision over the exchange, but in the main the work of management is left to the general manager and the secretary-treasurer. Each division elects a local agent to look after the work in that division. In addition, there are inspectors for each shipping point, but they are selected by the board of directors instead of by the local growers, in order to insure efficient and uniform inspection. The central office keeps in touch with the local agent to ascertain the probable amounts to be loaded at each shipping point day by day and later he is informed of the actual amount loaded. Thus the central office can see that the proper cars are provided and find markets for the products loaded. An effort is made to finish all the business each day. The local inspectors pass on the products as they are loaded; if they are up to standard they are permitted to carry the exchange

trade-mark; if not, they are loaded in a car of unbranded products. The central office takes care of the selling and forwards the proceeds to the local agents, who in turn make out the checks for the growers, payment being made within 24 hours after delivery of the goods. Under this system the growers do not have to wait for their returns. The association is able to do business on this basis, as a large surplus and good credit provide funds to cover payments to growers for all products delivered but unsold. Its present surplus is about \$150,000, and this, together with a paid-up capital of \$42,000, gives the exchange an ample working capital. Hereafter part of the net earnings will be returned to the growers in accordance with the amount of business transacted with the association.

The exchange makes an extensive use of the telegraph in selling products. Information with regard to the markets is secured daily from salesmen and representatives in the various market centers. In addition to the salesmen, brokers are also employed in effecting sales and in a large number of cities direct telegraphic communication with wholesalers is maintained. The fact that the exchange spends about \$20,000 annually for telegraph service shows how important this form of communication is. The sales are for the most part made f. o. b. loading point; consequently the buyer assumes the risk of delay and normal deterioration in transit. Losses that are not included in this risk, and losses resulting from occasional bills that are impossible to collect, are borne by the association.

The expenses of the business are met by charging a 5 per cent commission on the produce sold by the exchange and a 3 per cent commission on a small quantity of produce that is turned over to selling agents, which consists principally of odd lots and off-grade goods sold in near-by markets. The amount sold in this way never exceeds one-tenth of the total.

This organization has brought about an intelligent distribution of the products of its members and has greatly expanded the territory serving as a market for the products of the region. The inspection service has resulted in standardization which insures good produce to the consumer and good prices to the producer.

THE SHEBOYGAN COUNTY CHEESE PRODUCERS' FEDERATION, WISCONSIN.

The Sheboygan County Cheese Producers' Federation was organized on account of dissatisfaction among the farmers with the prevailing methods of marketing. There was a widespread feeling that the prices on the Plymouth Cheese Board were fixed and that the farmers were not receiving as much as they should. A number of meetings of farmers were held and in the summer of 1913 cheese producers' associations were organized at over 40 of the cheese factories, and

these united to form the Sheboygan County Cheese Producers' Federation.

In July, 1913, the federation appointed a manager and prepared to engage in active business. It was found, however, that all the available storage space had been previously engaged, making it impossible for the federation to start immediate operations. Another farmers' organization known as the Federated Farmers' Warehouse Co. was then formed and a warehouse and cold-storage plant was erected and made ready for use in the spring of 1914. The Cheese Producers' Federation then rented the warehouse from the Farmers' Warehouse Co. and engaged in business early in 1914.

The method of procedure adopted was to sell the cheese independently of the local cheese board. At first the federation had difficult work because of the opposition from some dealers and cheese makers, and also because the new company was not known, but a trade was gradually worked up by sending out a large number of letters to cheese buyers. From April 1 to December 31, 1914, 6,125,480 pounds of cheese were handled by the federation. A charge of one-fourth of 1 cent a pound was made to defray expenses. The total sales amounted to \$887,501.69. The figures for the year 1915 were not available at the time the federation reported, but a larger volume was handled than during the previous year.

TABLE IV.—*Summary of reports of 653 farmers' marketing organizations, showing paid-up capital and members, fees, value of buildings and equipment, and value of assets in excess of liabilities.*

Kind of business.	Num-ber re- porting.	Paid up capital and member- ship fees.	Building and equip- ment.		Assets in excess of liabilities. ¹	
			Num-ber re- porting.	Amount.	Num-ber re- porting.	Amount.
Grain elevators.....	328	\$2,553,463	326	\$2,857,555	328	\$4,361,875
Average.....		7,785		8,765		13,380
Creameries and cheese factories.....	172	716,996	174	1,199,424	173	1,093,339
Average.....		5,331		6,893		6,320
Fruit and produce.....	84	1,672,311	76	993,215	91	2,411,313
Average.....		19,908		13,069		26,499
Cotton warehouses and gins.....	26	179,778	27	204,772	26	321,146
Average.....		6,915		7,584		12,351
Miscellaneous.....	43	456,057	35	205,792	42	740,675
Average.....		10,606		5,885		17,635
Total.....	653	28,578,605	638	5,460,758	660	8,928,453
Average.....		43,765		8,559		13,528

¹ Paid-up capital stock and membership fees not taken into account as liability.

FINANCING AND BUSINESS PRACTICES.

Information with regard to financing and business practices was secured from some 700 typical farmers' organizations from a special survey. A summary of the reports is shown in Table IV. This table gives for each kind of organization the amount of paid-up capital and members' fees, the value of buildings and equipment, and the amount of assets in excess of liabilities. Much material was secured also by means of personal visits to organizations throughout the country and by interviews with bankers and others during the years 1914 and 1915.

The financing of the business operations is one of the important features in a cooperative enterprise and a weakness in this feature is the cause of many failures. The methods of conducting the business, products handled, distance from markets, and various other elements require that the plan of financing be suited to local conditions. For this reason no "cut and dried" plan, unless well suited to local conditions, should be adopted by new organizations.

TABLE V.—*Amounts borrowed and sources from which obtained, of 401 farmers and cooperative marketing associations, by classes.*

Kind of organization.	From banks.			From commercial firms.			From individuals.		
	Number reporting.	Amount.	Number reporting but not giving this item.	Number reporting.	Amount.	Number reporting but not giving this item.	Number reporting.	Amount.	Number reporting but not giving this item.
Elevators.....	154	\$1,040,950	16	47	\$722,813	17	10	\$36,500	2
Average.....		6,759			15,379			3,650	
Creameries.....	26	56,650	4				2	4,000	
Average.....		2,177						2,000	
Fruit and produce.....	63	1,115,275	3				1	1,500	
Average.....		17,703						1,500	
Cotton warehouses and gins.....	10	65,750	2	1	500				
Average.....		6,575			500				
Tobacco.....	2	85,000							
Average.....		42,500							
Miscellaneous.....	13	39,900	1				5	125,700	3
Average.....		3,069						25,140	
Total.....	268	2,403,525	26	48	723,313	17	18	167,700	5
Average.....		8,968			15,069			9,317	

TABLE V.—*Amounts borrowed and sources from which obtained, of 401 farmers and co-operative marketing associations, by classes—Continued.*

Kind of organization.	From banks and commercial firms.			From banks and individuals.			From commercial firms and individuals.		Total number reporting.	Number reporting amount borrowed.	Total amount borrowed.
	Number reporting.	Amount.	Number reporting but not giving this item.	Number reporting.	Amount.	Number reporting but not giving this item.	Number reporting.	Amount.			
Elevators.....	17	\$218,200	1	33	\$296,500	.....	1	\$20,000	298	262	\$2,334,963
Average.....		12,835	.....	.....	8,985	.....	.....	20,000	.....	.....	8,912
Creameries.....				1	6,000	.....	.....	.....	33	29	66,650
Average.....					6,000	.....	.....	.....	.....	.....	2,298
Fruit and produce.....				8	2,116,155	.....	.....	.....	75	72	3,232,925
Average.....					264,519	.....	.....	.....	.....	.....	44,902
Cotton warehouses and gins.....				1	1,750	.....	.....	.....	14	12	68,000
Average.....					1,750	.....	.....	.....	.....	.....	5,666
Tobacco.....				1	50,000	.....	.....	.....	3	3	135,000
Average.....					50,000	.....	.....	.....	.....	.....	45,000
Miscellaneous.....				5	33,347	1	.....	.....	28	23	198,947
Average.....					6,669	.....	.....	.....	.....	.....	8,650
Total.....	17	218,200	1	49	2,503,752	1	1	20,000	451	401	6,036,485
Average.....		12,835	.....	.....	51,097	.....	.....	20,000	.....	.....	15,054

FARMERS' GRAIN ELEVATORS.

The capital of farmers' grain elevators is in most cases only enough to provide the means of doing business, with very little in excess available as working capital. A considerable sum of money is required during the rush marketing season, since the elevator usually pays cash for the grain as it is delivered by the farmer. Several days elapse before returns for grain shipped are received, and often grain accumulates in the elevator. The little working capital the elevator has does not go far in paying for all the grain delivered. It is necessary to secure financial assistance from outside sources such as banks, commission firms, and individuals.

Using as a basis the average amount required from outside sources to transact the business of marketing the members' grain as shown by the reports from 262 elevators (Table V), it is a conservative estimate to place the total of the amounts borrowed in 1914 by the farmers' grain elevators at approximately \$30,000,000, the greater part of which was for short periods. This amount, while large in itself, is small when compared with the total value of the products marketed.

Security for loans obtained.—Out of 291 organizations reporting 99 gave company notes as security for loans obtained, 82 gave no security other than agreements to ship certain amounts of grain to commission houses making the loans, 8 gave mortgages on the

elevator and equipment, 5 used company notes indorsed by individuals, 12 used warehouse receipts of grain in storage, and 85 were required to give personal security of responsible individuals who were usually officers of the company or well-to-do members.

These reports show that as organizations at least one-third of the elevators reporting have no credit that is acceptable to bankers other than that which is given by responsible individuals who assume a personal responsibility. No cooperative business organization should be so conducted that it is necessary for a few members to assume large personal risks to carry on the enterprise which is of benefit to all members. Members should assume a liability proportionate to the benefits received or the amount of business which they do through the organization.

Interest.—Two hundred and ninety-eight elevators report interest rates as follows:

Number reporting	6	71	1	110	61	14	5	10	8	2	4	5	1
Rate, per cent	5	6	6½	7	8	10	8-10	6-7	7-8	6-8	5-6	5-7	5½-7

From these figures it is shown that over one-third of the elevators reporting pay 7 per cent for funds with which to carry on their business. Seventy-one secure funds for 6 per cent; and 14 are required to pay 10 per cent, which high rate in most cases is due to the lack of approved collateral security, such as will be accepted by bankers generally. Several elevators have overdraft arrangements with the banks, paying from three-fourths of 1 per cent to 1 per cent per month on these overdrafts. If funds can be secured in any other way this practice should be discouraged. It is clearly brought out from these reports that rates of interests vary in the same territory, as, for example, Minnesota elevators are paying rates ranging from 6 to 10 per cent. Two companies within 10 miles of each other borrow from local banks, one paying 7 per cent and the other 10 per cent.

In the majority of cases where funds are obtained from commission firms the rate charged the elevator is 6 per cent, while in some cases as much as 8 per cent is charged. In an investigation conducted by the Office of Markets and Rural Organization, in collaboration with the University of Minnesota, it was found that of 158 elevators in the State borrowing funds, 51 per cent are financed wholly or in part by commission men, the average rate of interest charged being 6.74 per cent; 71.5 per cent are financed partially by local banks, the average rate being 7.39 per cent; and 13 per cent also borrowed from individuals, usually farmers, at the average rate of 6.25 per cent.

Length of loans.—Most of the loans made to elevators by banks and individuals are for short periods of from one to four months, or during the heavy marketing season. Forty-one elevators report securing loans payable on demand. Where funds are advanced by commission firms the business is handled on open account and after the year's business is closed final settlement is made. Thirty-five elevators secured loans for improvements on 12 months' time.

Some 14 elevators have an arrangement with the company's bank whereby sums not in excess of a certain amount are advanced to the elevators to take care of the business, interest being charged only on funds as advanced. By using this plan, interest is not paid on a large balance.

Advances to members on warehouse receipts.—Of 326 elevators reporting, 62 make advances to members on warehouse receipts. These advances range from small amounts to as high as 75 per cent of the market value of the grain. Two hundred and sixty-four report no advances.

As a rule, it is considered inadvisable to make advances to members on stored grain, as a practice of making these advances brings the elevator into a phase of the banking business which can better be done by the local banks. When borrowing from a bank, the patron of an elevator is required to pay interest on the borrowed funds although he may object to paying the elevator for a similar loan. He considers that since the elevator is in possession of his grain, it is not entitled to interest on money advanced, which he may assume as part payment on his property. As a matter of fact the advance is not a part payment, but purely a loan, since the title to the grain remains his, and he has been given a warehouse receipt. With all its advantages accruing to the profit of the holder, it is clear that loss of interest to the elevator on the money advanced becomes a charge against all the members of the association to the direct benefit of the individual borrowing member; a principle which can not be considered cooperative in any sense. Aside from this, the complications in accounting brought about by this practice are unfortunate. When patrons require loans from the elevator, such loans should be made an open account, or a personal note should be given. In both cases interest should be charged in accordance with the prevailing rate.

Sentiment and practice with regard to the storing of grain vary in the different States in accordance with the variety of the prevailing crops and the sentiment of the terminal market in which the sales are made. In the southwestern and eastern sections of the grain belt many elevator companies forbid storing, and the practice is discouraged generally. In the northwestern grain States storing and

hedging prevail in about 95 per cent of the elevators. Primary elevator capacity is not sufficient to hold all grain offered for storage during the height of the season. This fact has made it necessary for elevators to sell stored grain and to secure protection by hedging in the terminal markets. In certain instances elevator managers have taken advantage of the presence of the stored grain in the elevator and have speculated in futures to the direct loss of their employers because of inefficient methods of bookkeeping. The adverse sentiment which prevails in some producing sections with regard to grain storage is partially due to such losses.

An elevator which is financed by a commission firm is handicapped in some instances in that it is impossible to take advantage of other markets which may from time to time offer better prices than can be obtained in the one in which the commission firm is located. Elevators not dependent in any way upon the commission house can ship first to one market, then to another, and in this way promote competition among the commission men in securing the best prices possible. It must be remembered, however, that the commission houses have served a useful purpose in the financing of the farmers' elevators in that they sometimes gave financial aid when it was impossible to secure it elsewhere. Elevators are turning more and more each year to local sources for their funds, which is a fortunate arrangement, and it has been demonstrated that the elevator which is able to finance its operations without securing any outside help is in a position to obtain the best results. As soon as possible an elevator, by the accumulation of a surplus, should place its business in such shape that but little outside financial assistance is necessary. Where outside assistance is needed, it is preferable to obtain it from the local bank, using as security the company's surplus, and the general moral rating secured by conducting the business on a conservative and efficient basis.

FARMERS' CREAMERIES AND CHEESE FACTORIES.

The average farmers' creamery and cheese factory has little difficulty in financing its manufacturing and marketing operations, because of the plan of withholding payment to the producer until returns are received from products shipped. Manufacturing costs are small, and can be met from the returns received from sales. Where funds from outside sources are needed, the plant and equipment in most cases are amply sufficient to cover any loans secured and serve as a basis of credit.

As fast as milk or cream is received it is manufactured into butter or cheese, a large part of which is shipped immediately, very little being held in storage. Payment to the members is made for periods varying from two weeks to a month, on the basis of the average price

which the manufactured product brings, less the manufacturing, selling, and miscellaneous costs. For example, when two payments a month are made, the farmer will receive a check on the first of the month for his deliveries covering the period from the 1st to the 15th of the previous month, while on the 15th, payment will be made for deliveries from the 16th to the 30th of the previous month. In this way from two to four weeks elapse between the last delivery of the period and the time the settlement is made. This plan is followed by most of the country creameries and cheese factories in the United States, and there seems to be no objection on the part of the farmer to waiting from 15 to 30 days for his "cream check".

This system of making payments has met with such success among the cooperative plants that some privately owned factories have adopted the same plan. In some communities, however, cooperative creameries have been compelled to pay cash in order to compete successfully with privately owned plants that pay cash. In such cases it becomes necessary for the cooperative organization to secure funds from outside sources, or to create a surplus with which to cover the amount of the patron's products yet unsold for which the patron has been paid.

The amounts borrowed as shown by Table V, were required for meeting the general running expenses of the business, purchase of supplies, in some cases for the addition of new machinery and repairs, and in other instances for advances to members.

Of 35 creameries reporting on the security given for loans, 14 used company notes, and it was necessary for 14 others to have the personal indorsement of the directors; 2 obtained funds without any collateral security; 3 gave mortgages on the plant and equipment, and 2, which had cheese in storage, obtained funds on warehouse receipts. This report does not take into account sums borrowed for the construction of the factory and initial equipment. At the outset, where loans for these purposes are secured, members have paid in capital stock or membership fees sufficient to furnish a basis of credit for the amounts required, which usually are obtained from banks. In some instances machinery companies extend credit for the equipment.

Interest.—Thirty-two creameries report interest rates as follows:

Number reporting.....	13	8	8	1	2
Rate, per cent	6	7	7-8	8	10

The rates charged vary in different localities and depend upon the season, length of loan, and credit rating of the organization.

Length of loan.—Seven organizations use borrowed money during three months, and six require it from two to three months for advances to members in the summer, when deliveries of milk are heavy.

Seventeen report using borrowed funds from 3 to 10 months, while three are working throughout the year on borrowed capital.

Conclusion.—One great difficulty with the average cooperative creamery is that no provision is made for replacement of plant and machinery, and such repairs, replacements, and improvements as are made are charged against the deliveries of the members until paid, in as large amounts as the business will stand. This is also true in purchasing creamery supplies, such as tubs and salt. The returns of a few months' shipments, amounting to several hundred dollars, will pay for supplies which are used for a period of a year or more. The supplies which are used throughout the year should be prorated in such a manner that each member contributes to the cost of these supplies in proportion to his year's business with the organization.

Provision should be made by which a small amount is withheld from the returns, to be placed in a fund from which supplies, repairs, and improvements can be paid. This fund should also be charged with reserves for depreciation on plant and machinery. By using this method funds are available which make it possible to take advantage of cash discounts in buying supplies, and the cost of repairs and improvements can be adjusted equitably. In the setting up of a reserve for depreciation on the plant and equipment, replacements can be made without special assessments, and money is available to make such replacements when necessary.

It is surprising to find that but a small number of the farmers' creameries and cheese factories keep accurate accounting records, as heretofore attention has been centered in the manufacturing end of the enterprise. There is great need for an improvement in the accounting and general business management of these organizations. To show the true state of the business, expert audits are needed. The present unsatisfactory condition is recognized by bankers, and has affected the financial standing of the average farmers' creamery or cheese factory.

FRUIT AND PRODUCE ASSOCIATIONS.

Fruit and produce marketing organizations which pool the members' products generally require considerable sums of money in order to meet early marketing expenses and make advances to the growers, since in most cases several weeks elapse between the delivery of the members' product and the returns from the market. It is necessary for the growers to have funds with which to meet picking and packing expenses. Owing to the fact that independent buyers are willing to pay for the fruit upon delivery, the cooperative organizations at the outset have made as liberal advances to the members as possible. Various plans have been devised by which the association can secure funds from outside sources, since in many cases it is impracticable

to accumulate a surplus large enough to meet the early advances, and as the money is required only for a short time, if accumulated it would be idle a large part of the year.

Heretofore perishable products have not been considered as good collateral by bankers in making loans to business enterprises, but perishable products marketed through an efficient organization are now considered good security by many bankers in making loans to such cooperative marketing associations. The amount of money required in handling perishable products will vary according to the size of the business and the methods of conducting it. Some organizations which conduct merely a consignment business and do not make advances to the growers need but a small amount with which to meet general running expenses. In many cases this is provided by money received from the issuance of capital stock, membership fees, or the accumulation of a surplus a sufficient part of which is in such shape that it can easily be converted into cash. Many organizations have developed a large f. o. b. business, making drafts against shipments, making arrangements with the bank to honor them, and placing them to the credit of the association. This provides funds for immediate use and materially decreases the amount of outside help needed in financing. In cases where pools are made, advances to the members are often necessary as the pool may not be entirely closed until months after the first receipts come in. If it is possible to secure sufficient funds to make the early advances, the returns from shipments as received will take care of other amounts advanced to the growers. In some of the successful produce associations located in the Atlantic States, the organization buys the members' product outright, paying for it at the time of delivery. Under this plan of operation large sums are necessary.

Security for loans obtained.—Of the organizations reporting on the amounts borrowed as shown by Table V, 38 gave association notes as security. Forty-six gave personal security, that is, company notes indorsed by the directors or individual members who were considered financially responsible. Three reported having given no security, as bankers advanced funds on overdraft as required. Two found it necessary to give mortgages on the packing plants. One association has obtained about \$300,000 from bankers on warehouse receipts covering nuts in storage. One secured a large loan from bankers on warehouse receipts for apples which were in storage.

These figures show that over half the organizations are able to borrow the funds necessary to make advances to members and to meet the expenses of the early marketing season, without security other than that which the organization can give, but a surprisingly large number, or 26 out of 72 organizations, are so organized that it

requires the personal security of directors or members to finance the operations.

Interest.—Seventy-six organizations report rates of interest as follows:

Number reporting.....	28	10	3	7	20	1	5	2
Rate, per cent	6	7	6-7	7-8	8	8-10	10	12

The rates of interest vary from 6 to 12 per cent. The two associations paying 12 per cent are badly in need of reorganization, and have had considerable difficulty in obtaining funds. The money which is procured is used for short periods and commands a high rate of interest. The associations on the Atlantic coast and in the Middle West as a rule secure funds at the rate of 6 per cent. Some of the larger organizations on the Pacific coast, owing to the large amounts which are borrowed, and their excellent business standing, are able to secure loans at from 6 to 7 per cent, while the rate which is charged individual producers by the banks is considerably higher. One of the large distributing agencies in the Pacific Northwest borrowed in the neighborhood of \$400,000 in one season, most of which was advanced to members for deliveries of fruit. The five organizations which report a 10 per cent rate borrowed small amounts at the time of the year when money in farming communities commands a premium. However, these organizations have an insufficient amount of capital, and from a business point of view are paying more for the money than would be necessary if the organization were better financed and a surplus set aside to help carry the expenses of the early marketing season.

Length of loans.—Of 74 associations reporting on the period for which funds from outside sources were needed, 21 report that they require outside assistance only during three months, or during the early part of the marketing season; 7 require funds for 6 months; the others vary from 1 to 12 months, but the larger part of them borrow for a short period, or from 1 to 4 months.

It is possible only during years of good marketing conditions to make advances amounting to a high percentage of the total amount due the grower. In years when markets are bad it is necessary to be very conservative in making advances, as there is a possibility of overpaying. The fruit held in storage may not produce the returns which were anticipated in the early season. In 1913 it was possible for the large distributor in the Pacific Northwest to secure advances on apples. Some banks solicited this business and offered to loan as high as \$1 a box at 6 per cent interest on all fruit in storage. During 1914, however, when the crop was large and markets were more or less demoralized, it was almost impossible to secure advances from

banks or cold storage companies. One large packing firm offered to make advances of 12½ cents per box at 8 per cent interest. Upon the improvement of conditions later in the season it was possible for the large distributors to negotiate a heavy loan on the basis of 35 cents a box. This was for only "fancy" and "extra fancy" grades, however, which were the best storage stock. In spite of this situation the stronger growers' organizations in the Pacific Northwest were advancing to the growers as much as 40 cents per box on all varieties, grades, and sizes, which was an exceptionally liberal advance, and showed that the organizations were in an excellent condition even in a period when marketing conditions were unusually bad.

TABLE VI.—*Annual business of several of the larger cooperative fruit and produce associations in the United States.*

Name of association.	Product handled.	Year.	Sales.
California Fruit Growers' Exchange.	Citrus fruits.....	Yearending Aug. 31, 1915.	\$19,737,850.00
California Fruit Growers' Exchange Supply Co.	Members' supplies.....	Aug. 31, 1915.....	3,319,062.04
Eastern Shore of Virginia Produce Exchange.	Produce, potatoes principally...	1914.....	5,752,690.36
Monmouth County Farmers' Exchange.	do.....	1914.....	1,323,443.02
North Pacific Fruit Distributors	Deciduous fruits.....	1913.....	3,372,196.30
Georgia Fruit Exchange.....	Peaches.....	1913.....	2,250,000.00
Florida Citrus Exchange.....	Citrus fruits.....	1913.....	3,500,000.00
Puyallup and Sumner Fruit Growers' Association.	Fresh fruits; operates 2 canneries.	1914.....	1,300,000.00
American Cranberry Exchange.	Cranberries.....	1913.....	1,500,000.00

AGENCIES WHICH ASSIST COOPERATION.

Several agencies take an active interest in cooperative organization and render assistance in forming new associations and in giving aid to organizations already formed. Among such agencies may be mentioned the United States Department of Agriculture, the State agricultural colleges and experiment stations, State departments of agriculture, State marketing bureaus, and various organizations, companies, and individuals.

THE UNITED STATES DEPARTMENT OF AGRICULTURE.

Office of Markets and Rural Organization.—The Office of Markets and Rural Organization has been devoting considerable attention to cooperative purchasing and marketing; assistance has been rendered to organizations already formed and to localities contemplating an organization. In a number of instances personal visits have been paid to organizations and localities and, after the local conditions have been studied, recommendations have been made as to desirability of organization, method of operation, and similar subjects. In other instances similar assistance has been given by means of corre-

spondence. General information is available for those who are interested in the advisability of organization, the proper form, and the method of organizing and operating under various conditions. Suggested forms of by-laws have been furnished to a large number of organizations.

The accounting systems of existing cooperative associations have been studied and uniform systems of accounts have been perfected for elevators, fruit and produce associations, live-stock shipping associations, creameries, stores, and other types. Assistance in installing these systems has been given in a number of cases and educational work is carried on relating to better systems of accounts and more businesslike methods in the operation of cooperative enterprises. The matter of financing these associations has been studied and methods have been worked out for various organizations.

In addition to the general survey of cooperative marketing in the United States made by this office, more detailed surveys have been made of certain classes of organizations. Several bulletins dealing with cooperation and cooperative marketing associations have been issued, and these have served as a means of furnishing a large number of people with information relating to the subject.

The Dairy Division, Bureau of Animal Industry.—The Dairy Division is interested principally in the production and manufacture of dairy products, and therefore keeps in touch with a large number of farmers' creameries and cheese factories. While most of the aid given to these plants is along manufacturing lines, considerable assistance is given also in the matter of creamery organization and management.

States Relations Service.—The States Relations Service indirectly through the county agents in the different States renders assistance to farmers' organizations and farmers desiring to organize. In many States the organization work of the agricultural colleges and experiment stations is carried on largely through the county agents.

WORK OF THE STATE AGRICULTURAL COLLEGES, STATE DEPARTMENTS OF AGRICULTURE, AND DEPARTMENTS OF MARKETS ALONG COOPERATIVE LINES.

Among the agencies engaged in furthering cooperation among farmers should be mentioned the State agricultural colleges, departments of agriculture, and departments of markets. Some of these institutions have taken an active part in organizing and assisting farmers' cooperative associations, others have furthered cooperation in an educational way, and a few have not up to the present time conducted any work of this kind. The scope of the work along cooperative lines at some of these institutions is now being widened. A number of agricultural colleges and State departments have recently undertaken work in marketing in cooperation with the Office of Mar-

kets and Rural Organization, United States Department of Agriculture, and some of these are giving special attention to cooperative organization problems. Information was secured from nearly all of the agricultural colleges and a number of State departments with regard to their activities along cooperative organization lines, but on account of the rapid expansion which is now taking place in this field of endeavor, it has not been deemed practicable to include a complete statement of the work that each one of these agencies is performing.

COOPERATIVE LAWS.

In the main the laws regulating the formation of cooperative associations in the various States are of two types. Some State laws are very general while others outline in detail the methods of forming an organization and managing its business. The general laws leave the details to be worked out by each individual organization, and supporters of this type of cooperative law believe that it is preferable because it allows an organization more latitude and gives greater assurance of securing the form of organization that is best suited to the needs of the community. Some argue that detailed laws attempt to force an idealistic form of cooperation on persons who are beginners in this field of activity, but supporters of the detailed laws maintain that the surest method of bringing about true cooperation is by outlining in full a method of organization that embodies the true principles of cooperation. There is no doubt that a detailed law insures greater uniformity of organization than it is possible to secure under a general law.

The differences between cooperative and noncooperative forms of organizations and the advantages and disadvantages of each type are questions which need careful study, for which few individuals have either the time or the facilities. If detailed cooperative laws had been in existence in all the States at the time when the farmers' organization movement started, it is unquestionably true that the proportion of truly cooperative organizations would now be very much larger than it is in those States where such laws are not in operation. Detailed laws serve to educate people along cooperative lines, and for that reason it is not necessary to wait until the beginner's stage has been passed before such laws are enacted.

Cooperative laws usually state the minimum number of persons that may organize and give the kind of business in which they may engage. The method of incorporation sometimes is outlined, although this is not always done, as in some States the associations are referred to the general corporation laws for this information. The laws often include restrictions regarding the board of directors and the officers. General laws usually leave questions concerning the capital stock for each association to decide, while detailed laws usually prescribe the

minimum and maximum amounts of capital stock, share values, the limit on individual ownership of shares, the issuance of shares, and the transfer of stock. Most of the laws recognize the importance of regulating the voting power, and the majority state that each member is to have one vote regardless of the amount of stock owned. Regulations concerning proxy voting and voting by mail are sometimes included.

The method of distributing earnings, if any, is, or should be, an important feature of cooperative laws. Some States leave this to each association to decide, while other States provide in detail the method to be followed. Laws of the latter kind usually limit the dividends on stock to a fair rate of interest, provide for a reserve fund and sometimes an educational fund as well, and for the division of the remainder of the earnings in the form of a patronage dividend. Some laws specify that patronage dividends are to be paid only to members, others include all patrons or leave it to be decided by the association whether or not patrons who are not members shall receive patronage dividends. Several States provide that patronage dividends to non-members shall be at a lower rate than to members. In a few instances the laws provide in detail the method of apportioning the earnings, but make it possible for the associations formed thereunder to revise this, if desired. Because of the fact that many people fail to recognize the desirability of a truly cooperative method of distributing the earnings of an association, it seems advisable that cooperative laws should make such a method obligatory. In this manner noncooperative organizations can be prevented from masquerading as cooperative, for, while some of the laws forbid organizations not formed under the cooperative law to use the word "cooperative" as part of their corporate name, if the method of distributing earnings is left to the association it may comply with the law and still be far from cooperative.

The points to be covered in the by-laws of cooperative organizations are sometimes outlined fully in the cooperative laws. In some cases provisions are made for the investment of the reserve fund and for the purchase of the business of other associations. Provisions are frequently made whereby existing organizations are permitted to reorganize under the cooperative law by complying with the requirements of the law. Other regulations often included are for dissolution of an organization, the requiring of annual reports, and the limiting of the use of the word "cooperative."

COOPERATIVE LAW SUMMATIONS.

The condensed summary of the State laws relating to the formation of cooperative organizations (pp. 66, 67) shows the main points of the State cooperative laws concerning which information has been

secured in this survey. Thirty States are represented in this digest, but there are 33 laws, as Colorado, Michigan, and Washington each have two separate acts, one providing for nonstock organizations and the other providing for organizations with capital stock. This table includes only a general outline of the State cooperative laws and it must not be considered as giving complete information with regard to these laws. Persons desiring to organize a cooperative association should study the statutes of the State in which the organization is to be formed, and if necessary legal advice should be secured in order that the organization may meet all the requirements of the law.

SCOPE AND PURPOSE.

Most of the laws provide in detail for the lines of business in which such organizations may engage, but a few of the laws make no restrictions in this matter, it being permissible to engage in any lawful business. Where the scope and purpose are fully outlined, the field covered is usually sufficiently broad to make possible organization for any lawful purpose.

MINIMUM NUMBER OF MEMBERS THAT MAY ORGANIZE.

All but three of the laws give the minimum number that may organize. Two of the States that do not mention this point provide for the minimum indirectly by specifying the number of directors and officers each association must have. Four of the laws provide that not less than 3 persons are necessary in order to organize; 5 is the most common minimum, for this is the requirement of 18 laws; four laws require not less than 7 members; one places the minimum at 10; one places it at 20; two require at least 25 members, and the other three make no mention of this point.

FILING OF ARTICLES OF INCORPORATION.

As will be noted from the summary, the methods of filing the articles of incorporation vary considerably in the different States. Twenty-two of the laws provide for filing the articles of incorporation with the secretary of state, and 14 of this number provide for the filing with some other official as well, usually the clerk of the county in which the principal place of business is located, the recorder of deeds, clerk of court, or county auditor. A few of the laws provide for filing with some local township or county officer only, as for instance the town clerk or the register of deeds. Four of the laws do not stipulate the method of filing, and three laws state that cooperative organizations shall be governed by the regulations provided for general corporations in this matter. Some of the laws have provisions in regard to the fees to be charged for filing, while in other States cooperative organizations pay the fee required of general corporations.

MANAGEMENT.

Twenty-two of the laws have clauses with regard to the management of the associations. Thirteen laws provide for a board of directors of not less than five members, and 11 of this number also specify what officers the associations shall have; four laws provide for a board of not less than three directors, and two of these also provide for the officers. One law states that the board of directors shall consist of not less than five or more than nine members; one law provides for a board of managers made up of the president, secretary-treasurer, and three directors, and in three of the laws the question of management is left to the association to be stipulated in its by-laws. The officers usually specified are president, one or more vice presidents, secretary and treasurer, or a combined office, secretary-treasurer.

CAPITAL STOCK.

The regulations relating to capital stock usually included in cooperative laws are the maximum and minimum amount of capital stock, the value of a share of stock, when stock may be issued, limits on individual ownership of stock, and restrictions on the transfer of stock. Seven of the cooperative laws provide for the organization of associations without capital stock. Eleven laws make some provision with regard to share value or with regard to the amount of stock that may be issued. Ten laws provide that shares are not to be issued to stockholders until they are paid for in full. The amount of capital stock which one person may own is limited to \$1,000 in 10 of the laws; in addition one of these laws specifies that one person must not own more than one-third of the stock outstanding, and another gives an association the power to change the limit if it desires to do so. Three of the laws state that the limit on individual stock ownership shall be as prescribed in the by-laws of the association. Four laws provide that a person must not own more than 20 per cent of the stock and one law limits this to 10 per cent. One law places the limit at one share, one at five shares, one at \$400, and one at \$5,000. Four laws do not touch on this matter at all and seven relate to nonstock organizations.

Eleven laws have provisions relating to the transfer of shares of stock, six of this number making it necessary to have the permission of the board of directors of the association before transferring the stock; four laws leave this matter for each association to include in its by-laws, and one law makes it possible for an association to have a clause in the by-laws providing that the association shall have the first opportunity to purchase any stock that may be for sale.

It is frequently desirable for two associations to consolidate or for one association to hold stock in another and 14 of the laws have made some provision for this. Some of the laws limit the amount that

may be so invested, and some also provide for the authority to invest. The most common form is to limit the amount that may be thus invested to 25 per cent of its capital, and also to provide that it must be decided by a majority or a two-thirds vote of the members.

VOTING POWER.

One of the underlying principles of cooperation is that the members of an organization shall have equal voting power in the meetings. Twenty-three of the cooperative laws provide that each member shall have one vote, regardless of the amount of stock he holds. Two laws specify that each association shall set forth in its articles of incorporation or by-laws the rules to be followed in this matter. .

Seventeen laws touch on the question of proxy voting, and voting by mail; seven provide for voting by mail if the votes so cast are accompanied by a written copy of the question voted on; five leave the questions of proxy voting and voting by mail for each association to stipulate in its by-laws; two permit both voting by mail and by proxy; one provides for voting by mail but forbids proxy voting; one forbids proxy voting but states that an association may provide in its by-laws for voting by mail; and one forbids proxy voting and does not mention voting by mail.

DISTRIBUTION OF PROFITS.

It is in the matter of distributing profits that so many organizations fall short of being cooperative. The cooperative laws vary considerably in their provisions with regard to this important point. Some laws merely state that the profits shall be distributed to those entitled to them, as provided in the by-laws, while other laws go into detail as to the manner of dividing the profits. The matter of distributing the profits is considered under four heads—the payment of interest on capital stock, the setting aside of a reserve fund, the provisions for an educational fund, and the distribution of profits in the form of patronage dividends.

Eleven laws leave the question of stock dividend or interest on money invested in shares of stock, to be decided by each association, and inserted in the by-laws; four laws do not mention this at all; six laws provide that the stock dividend shall not exceed 6 per cent, but four of the six grant the associations the privilege of changing this if they so desire; two laws give 8 per cent as the maximum rate; two laws place the maximum at 10 per cent, subject to revision by the associations; one places the maximum at 5 per cent, and one at 5 or 6 per cent.

Nine laws provide that the setting aside of a reserve fund shall be done in the manner stipulated by the by-laws; ten do not mention

the matter of a reserve fund; nine provide that not less than 10 per cent of the net earnings shall be set aside until a fund equal to 30 per cent of the paid-up capital has been accumulated, though six of the nine provide that the associations may revise this; one law provides for the setting aside of not less than 5 nor more than 25 per cent of the net earnings, and another from 10 to 25 per cent; another law stipulates that not less than 5 per cent shall be set aside until 30 per cent of the paid-up capital has been accumulated; one provides for the setting aside of 10 per cent until 20 per cent of the paid-up capital has been accumulated, and another for not less than 10 per cent until 50 per cent has been accumulated.

Eleven laws provide that the educational fund shall be as specified in the by-laws; 13 fail to make any mention of an educational fund; six provide that 5 per cent of the net profits shall be set aside for such a purpose, but four of the six grant the association the privilege of changing this; one law provides for an educational fund of not to exceed 5 per cent of the net profits; one provides for 2 per cent subject to revision by the associations; and one provides for the use of $2\frac{1}{2}$ per cent of the net profits for this purpose.

A question that arises in connection with the payment of patronage dividends is whether or not nonmembers shall have any share in the profits of an organization. Twelve cooperative laws state that nonmembers shall or may receive patronage dividends, and several of these specify that the rate to nonmembers shall be one-half the rate paid to members. Several of the laws do not touch on this point at all, and a number merely state that the by-laws shall decide in regard to the paying of patronage dividends.

DISSOLUTION.

Sixteen laws have provisions regarding the dissolution of organizations formed thereunder. Eight laws permit dissolution upon written request of two-thirds of the members; five provide that if an association has not paid any stock dividends for five consecutive years, five or more members may petition the court to have the organization dissolved; the law of one State provides that five members may petition for dissolution of an organization which has failed to pay stock dividends for three consecutive years; one law provides for dissolution by a majority vote; and one states that the procedure shall be the same as for corporations under the general corporation law.

ANNUAL REPORTS.

Sixteen laws specify that all associations formed thereunder shall make certain reports. Ten of these provide for an annual report to the secretary of state; two of the 10 also provide for reports to other departments, one to the State division of markets and

another to the agricultural college of the State; two laws require that creameries report to the dairy and food commissioner of the State; one law requires reports to be sent to the commissioner of agriculture; one specified that reports shall be filed with the county clerk and also with the State Bureau of Statistics of Labor and Commerce; two laws have provisions in regard to filing or posting of reports at the principal office of the organization.

PROVISIONS FOR EXISTING ORGANIZATIONS.

In 16 of the States the cooperative laws outline the method of procedure for existing organizations that wish to come under the cooperative law. The common method is by complying with the provisions of the law and filing with the secretary of state a sworn statement of the fact that the organization by a majority vote has expressed such a desire.

USE OF WORD "COOPERATIVE".

Eleven of the laws impose certain restrictions on the use of the word "cooperative" in the name of a concern in order to prevent its misuse. The usual requirement is that the word "cooperative" must not be used in the name of any organization formed after the passage of the cooperative law which does not comply with the requirements of that law.

DIGEST OF STATE COOPERATIVE LAWS.

ALABAMA.

Scope and purpose: Mutual aid, benefit, industrial.

Number who may organize: Five or more.

Filing of articles of incorporation: With judge of probate in county in which principal place of business is located.

Filing fee: Same as for other corporations. Judge of probate shall receive 15 cents per 100 words, and \$2.50 for examining articles.

Management: Not less than five directors.

Capital stock: Not less than \$5,000.

CALIFORNIA.

Scope and purpose: Any lawful business.

Number who may organize: Five or more.

Filing of articles of incorporation: Clerk of county in which the principal place of business is located, a copy with the secretary of state.

Filing of amendments: With clerk of county.

Capital stock: Nonstock.

Transfer of memberships: May be transferred by board of directors.

Voting: Each member one vote.

Voting by mail or by proxy: May be provided for in by-laws.

Distribution of earnings: According to by-laws.

Dissolution: Upon written request of two-thirds of the members.

COLORADO (NONSTOCK).

Scope and purpose: Production, preserving, drying, canning, shipping, or marketing of agricultural, viticultural, horticultural, dairy, or apiarian products.

Number who may organize: Three or more.

Filing of articles of incorporation: With secretary of state and recorder of deeds in county in which the principal place of business is located.

Filing fee: \$15 to secretary of state.

Filing of amendments: With secretary of state and with clerk of county.

Capital stock: Nonstock.

Transfer of memberships: May be transferred with the consent of the board of directors.

Voting: Each member one vote.

Voting by mail and by proxy: No proxy voting. By-laws may provide for vote by mail.

Dissolution: Upon written request of two-thirds of the members.

COLORADO (CAPITAL STOCK).

Scope and purpose: Any lawful business.

Number who may organize: 10 or more.

Filing of articles of incorporation: With secretary of state.

Filing fee: Same as for general corporations.

Stock ownership: May be limited by by-laws.

Distribution of earnings: According to by-laws.

CONNECTICUT.

Scope and purpose: Purpose of trade, or any lawful mercantile, mechanical, manufacturing, or agricultural business.

Number who may organize: Seven or more.

Filing of articles of incorporation: With town clerk in town in which business is conducted.

Management: President, treasurer, and board of not less than five directors.

Capital stock: Not to exceed \$50,000.

Issuance of stock: When paid for in full.

Stock ownership: Limited to \$1,000.

Purchasing of business of other associations: Two or more associations formed under this act may consolidate.

Voting: Each member one vote.

Distribution of earnings: According to by-laws, provided that 10 per cent of net profits will be appropriated for contingent fund until this fund equals 20 per cent of capital stock.

Dissolution: Upon written request of two-thirds of the members.

Annual reports: To be made to the secretary of state.

FLORIDA.

Scope and purpose: Production, preserving, drying, packing, shipping, or marketing of horticultural and agricultural products.

Number who may organize: Three or more.

Filing of articles of incorporation: Same as for other corporations.

Management: Not less than three directors.

Capital stock: Nonstock.

Transfer of memberships: By permission of the board of directors.

Voting: As provided in the articles of incorporation.

Proxy voting: May be provided in by-laws.

Dissolution: Upon written request of two-thirds of votes.

ILLINOIS.

Scope and purpose: General mercantile, manufacturing, or producing business.

Number who may organize: Five or more.

Filing of articles of incorporation: With secretary of state.

Filing of amendment: With secretary of state and recorder of deeds in county in which principal place of business is located.

Management: Not less than five directors. Officers shall be president, vice president, secretary, and treasurer. The last two may be combined.

Capital stock: Shares not less than \$5 or more than \$100 in value.

Stock ownership: Limited to five shares.

Transfer of stock: By-laws may provide that corporations shall have first right to purchase any stock for sale.

Purchasing business of other associations: By a two-thirds vote of at least two-thirds of the members, the corporation may invest its surplus to the extent of 25 per cent of its paid-up capital in the capital stock of other cooperative associations; the board of directors may invest not to exceed 10 per cent of the paid-up capital in the same manner.

Voting by mail and proxy: Vote by mail to count if voter has been notified in writing and copy of question is attached to vote. Written proxies are permitted.

Distribution of earnings: According to by-laws.

Annual reports: Made to secretary of state before March 1.

Provisions for existing organizations: May come under this act by filing sworn statement that members have so decided by at least two-thirds majority.

Use of word "cooperative": No corporation formed after passage of act permitted to use the name "cooperative" unless complying with this act.

INDIANA.

Scope and purpose: Any lawful business.

Number who may organize: Twenty-five or more.

Filing of articles of incorporation: With secretary of state.

Filing fee: Same as for other corporations.

Stock ownership: May be limited by by-laws.

Transfer of stock: May be regulated by by-laws.

Distribution of earnings: According to by-laws.

Provisions for existing organizations: May come under act by filing declaration with secretary of state.

IOWA.

Scope and purpose: Agricultural, dairy, mercantile, manufacturing, or mechanical business.

Number who may organize: Five or more.

Filing of articles of incorporation and amendments: With secretary of state and the recorder of deeds of the county in which the principal place of business is located.

Filing fee: Ten dollars to secretary of state for filing articles, and \$5 for amendments, provided that if capital stock is less than \$500 the fee shall be \$1. Recorder of deeds to receive the usual recording fee.

Management: Not less than five directors. Officers shall be president, one or more vice presidents, secretary, and treasurer. The last two may be combined.

Issuance of stock: When paid for in full.

Stock ownership: Not to exceed \$1,000.

Purchasing of business of other associations: By a majority vote may invest not to exceed 25 per cent of its capital.

Voting: Each member one vote.

Voting by mail: Vote by mail to count if member has been notified in writing and copy of question is attached to vote.

Distribution of earnings: Subject to revision by associations, not to exceed 10 per cent dividend on stock, not less than 10 per cent of net profits until 50 per cent of paid-up capital is accumulated for a reserve fund, 5 per cent of net profits for an educational fund, patronage dividends to members and employees.

Dissolution: If no dividends are paid for five consecutive years, five members may petition district court.

Annual reports: To secretary of state before March 1.

Provisions for existing organizations: Filing sworn statement with secretary of state that this has been decided by a majority vote.

Use of word "cooperative:" No corporation formed after passage of this act shall use the name "cooperative" unless this act is complied with.

KANSAS.

Scope and purpose: Any agricultural, mercantile, dairy, mining, manufacturing, or mechanical business.

Number who may organize: 20 or more.

Filing of articles of incorporation: With secretary of state.

Management: Not less than five directors. Officers shall be president, one or more vice presidents, secretary, and treasurer. The last two may be combined.

Stock ownership: Not over 10 per cent of capital stock.

Voting: Each member one vote.

Distribution of earnings: According to by-laws.

Annual reports: Made to secretary of state.

Provisions for existing organizations: Filing sworn statement showing that association has decided by majority vote to come under this act and paying fees.

Use of word "cooperative": Organizations must not use title "cooperative" unless act is complied with.

MASSACHUSETTS.

Scope and purpose: Any agricultural, dairy, or mercantile business.

Number who may organize: Seven or more.

Capital stock: Not to exceed \$10,000.

Stock ownership: Not to exceed \$400.

Investing reserve: May invest surplus in buildings of association or lend to members on real estate mortgages.

Voting: Each member one vote.

Distribution of earnings: Capital stock dividends not to exceed 5 per cent; not less than 10 per cent of net profits for reserve fund until at least 30 per cent of paid-up capital is accumulated; not to exceed 5 per cent of net profits for an educational fund; patronage dividends paid to stockholders and may be credited to nonstockholders as payment on share of stock at one-half the rate to stockholders.

Provisions for existing organizations: By filing sworn statement that association has by a majority vote decided to come under this act and paying fee of \$1.

MICHIGAN (NONSTOCK).

Scope and purpose: Any lawful purpose other than pecuniary profit.

Number who may organize: Five or more.

Filing of articles of association: With secretary of state and the clerk of the county in which principal business is conducted.

Capital stock: Nonstock.

Provisions for existing organizations: Any corporation not for pecuniary profit may reincorporate under this act.

MICHIGAN (CAPITAL STOCK).

Scope and purpose: Merchandise, agricultural, or manufacturing business.

Number who may organize: Five or more.

Filing of articles of incorporation and amendments: With secretary of state and clerk of county in which principal place of business is located.

Filing fee: Same as other corporations.

Management: Not less than five directors. Officers shall be president, vice president, secretary, and treasurer. The last two may be combined.

Issuance of stock: When paid for in full.

Stock ownership: Not over \$1,000.

Voting: Each member one vote.

Voting by mail: Vote by mail to count if voter has been notified in writing and copy of question is attached to vote.

Distribution of earnings: Subject to revision by the association, 6 per cent stock dividends, 10 per cent of net profits for reserve fund until 30 per cent of paid-up capital is accumulated, patronage dividends may be paid to nonmembers at one-half the rate to members.

Annual reports: Made to secretary of state.

Provisions for existing organizations: May come under act by complying with its provision and filing sworn statement with secretary of state.

MINNESOTA.

Scope and purpose: Any lawful mercantile, manufacturing, or agricultural business.

Filing of articles of incorporation: With register of deeds of the county in which the principal place of business is located.

Management: President, treasurer, and not less than three directors.

Capital stock: Not to exceed \$100,000. For creameries not to exceed \$25,000.

Issuance of stock: When paid for in full.

Stock ownership: Not over \$1,000.

Voting: Each member one vote.

Distribution of earnings: According to by-laws.

Dissolution: If no dividends are paid for five consecutive years five or more members may apply to district court.

Annual report: Creameries report to dairy and food department.

MONTANA.

Scope and purpose: Trade or any branch of industry, purchase or distribution of commodities for consumption, borrowing or lending money.

Number who may organize: Not less than three nor more than seven incorporators.

Filing of articles of incorporation: Secretary of state.

Filing fee: \$5.

Capital stock: Shares not less than \$10 or more than \$5,000 each.

Stock ownership: One share each.

Voting: Each member one vote.

NEBRASKA.

Scope and purpose: Any lawful business.

Number who may organize: Not less than 25.

Filing of articles of incorporation: With secretary of state.

Filing fee: Same as for other corporations.

Stock ownership: According to by-laws.

Transfer of stock: According to by-laws.

Distribution of earnings: According to by-laws.

Provision for existing organizations: May come under act by filing sworn statement with secretary of state.

NEVADA.

Scope and purpose: Any lawful business.

Number who may organize: Five or more.

Filing of articles of incorporation: With secretary of state and clerk of county in which principal place of business is located.

Management: According to by-laws.

Capital stock: Nonstock.

Transfer of memberships: Memberships may be transferred by permission of the board of directors.

Voting: Each member one vote. Voting by mail may be provided for in by-laws.

Distribution of earnings: According to by-laws.

Dissolution: By written request of two-thirds of the members.

NEW JERSEY.

Scope and purpose: Any lawful mechanical, mining, manufacturing, or trading business.

Number who may organize: Seven or more.

Filing of articles of association: Approved by chief of bureau of statistics of labor and industries. Filed with clerk of county in which principal place of business is located.

Management: Not less than five directors. Officers shall be president, treasurer, and secretary.

Capital stock: Share value not to exceed \$50.

Issuance of stock: When paid for in full.

Transfer of stock: According to by-laws.

Purchasing of business of other associations: May have interest in another society to the extent of one-third of its paid-up capital.

Voting: Each member one vote.

Distribution of earnings: According to by-laws.

Dissolution: Same as any other corporation.

Annual reports: Made to clerk of county and chief of bureau of statistics of labor and industries.

NEW MEXICO.

Scope and purpose: Production, preserving, drying, packing, shipping, or marketing of agricultural, viticultural, or horticultural products.

Number who may organize: Three or more.

Filing of articles of incorporation: As provided by State law.

Management: According to by-laws.

Capital stock: Nonstock.

Transfer of memberships: Not to be transferred without consent of board of directors.

Purchasing of business of other associations: Associations formed under this act may consolidate upon two-thirds vote of members. Two or more associations may make use of the same agencies.

Voting: According to articles of incorporation.

Voting by mail: According to by-laws.

Dissolution: Upon request of members representing two-thirds of total vote.

NEW YORK.

Scope and purpose: General producing, manufacturing, and merchandising business.

Number who may organize: Five or more.

Filing of articles of incorporation: Same as provided for other corporations.

Management: Not less than five directors. Officers shall be president, one or more vice presidents, secretary, and treasurer. The last two may be combined.

Capital stock: Shares of \$5 each.

Issuance of stock: When paid for in full.

Stock ownership: Not over \$5,000.

Transfer of stock: By written consent of corporation.

Purchasing of business of other associations: Not to exceed 25 per cent of its capital.

Voting: Each member one vote.

Voting by mail: Permitted if member has been notified of question and a copy is attached to vote.

Distribution of earnings: Stock dividends not to exceed 6 per cent, not less than 10 per cent of net earnings for reserve fund until 30 per cent of paid-up capital is accumulated, 5 per cent of net earnings for an educational fund, patronage dividends to members and employees and at one-half rate to nonmembers.

Dissolution: If no dividends are paid for five consecutive years, five or more members may petition supreme court of county.

Annual reports: Made to secretary of state.

Provision for existing organizations: Filing sworn statement with secretary of state.

Use of word "cooperative": Not to be used in name of any corporation formed after passage of this act unless act is complied with.

NORTH CAROLINA.

Scope and purpose: Any agricultural, dairy, mercantile, mining, manufacturing, or mechanical business.

Number who may organize: Five or more.

Filing of articles of incorporation and amendments: With secretary of state and clerk of superior court in county in which principal place of business is located.

Filing fee: \$10 and fee allowed by law to secretary of state, \$2 when capital stock is less than \$1,000. Fifty cents to clerk of court. For filing amendments, \$5, or \$2 if capital stock is less than \$1,000.

Management: Not less than five directors. Officers shall be president, one or more vice presidents, secretary, and treasurer. The last two may be combined.

Stock ownership: Limited to 20 per cent of paid-up capital stock.

Transfer of stock: According to by-laws.

Voting: Each member one vote.

Voting by mail and proxy: Vote by mail to count if accompanied by a copy of the question. Proxies must be in writing.

Distribution of earnings: Subject to revision by association, stock dividends not to exceed 6 per cent, not less than 10 per cent of net profits to reserve fund until 30 per cent of paid-up capital is accumulated, not less than 2 per cent of net profits for an educational fund, patronage dividends to members and employees and to nonmembers at one-half rate.

Annual report: Made to secretary of state and division of markets and rural organization.

Provision for existing organizations: Filing sworn statement with secretary of state.

Use of word "cooperative": Not to be used in name of any organization hereafter formed unless this act is complied with.

NORTH DAKOTA.

Scope and purpose: Any lawful mercantile, manufacturing, agricultural, or industrial business.

Filing of articles of incorporation: With secretary of state.

Filing fee: \$10

Management: President, secretary, treasurer, and not less than three directors.

Capital stock: Not to exceed \$50,000.

Issuance of stock: When paid for in full.

Stock ownership: Not over \$1,000.

Voting: Each member one vote.

Distribution of earnings: According to by-laws.

Dissolution: If no dividends are paid in five years, five or more members may petition.

Annual reports: Creameries report to dairy commissioner.

OHIO.

Scope and purpose: Trade associations.

Distribution of earnings: According to by-laws.

OREGON.

Scope and purpose: Any lawful business.

Number who may organize: Five or more.

Filing of articles of incorporation and amendments: With secretary of state, clerk of county, and Oregon Agricultural College.

Filing fee: \$10 to secretary of state, 25 cents per 100 words to clerk of county. For amendments, \$5 to secretary of state and 25 cents per 100 words to clerk.

Management: President and four other directors.

Issuance of stock: When paid for in full.

Stock ownership: Not over one-fifth.

Purchasing of business of other associations: Not to exceed 20 per cent of its capital and reserve fund.

Voting: Each member one vote.

Voting by mail and proxy: May vote by mail. No proxy.

Distribution of earnings: Stock dividends not to exceed 6 per cent, not less than 5 or more than 25 per cent of net earnings for reserve fund, patronage dividends to nonmembers one-half the rate to members.

Dissolution: By written request of two-thirds of its members.

Annual reports: Made to secretary of state and Oregon Agricultural College.

Provisions for existing organizations: By filing sworn statement with the secretary of state.

Use of word "cooperative": Not to be used unless this act is complied with.

PENNSYLVANIA.

Scope and purpose: Productive or distributive business.

Number who may organize: Five or more.

Filing of articles of incorporation and amendments: With secretary of state and recorder of deeds of county in which principal place of business is located.

Filing fees: 10 cents for each 100 words to secretary of state and recorder of deeds.

Capital stock: Shares \$5 to \$25.

Stock ownership: \$1,000. May be increased by vote of members.

Purchasing of business of other associations: By majority vote of members.

Voting: Each member one vote.

Voting by proxy: No proxy voting.

Distribution of earnings: Stock dividends 5 or 6 per cent (see law), not less than 2½ per cent of net profits for educational fund, patronage dividends to members and employees and to nonmembers at one-half rate.

Dissolution: By majority vote of the members.

Reports: Monthly reports to be posted in principal office.

Provision for existing organizations: May come under act by a majority vote.

SOUTH CAROLINA.

Scope and purpose: Agricultural, dairy, mercantile, mining, mechanical, or manufacturing business.

Number who may organize: Five or more.

Filing of articles of incorporation: With secretary of state.

Management: Not less than five nor more than nine directors. Officers shall be president, secretary, and treasurer. Last two may be combined.

Capital stock: Not less than \$100.

Stock ownership: Not over one-fifth.

Purchasing of business of other associations: By a majority vote, reserve may be invested in capital stock of other associations not to exceed 25 per cent of its capital.

Voting: Each member one vote.

Distribution of earnings: May be revised by association, stock dividends not to exceed 6 per cent, not less than 10 per cent of net profits to reserve fund until at least 30 per cent of paid-up capital stock is accumulated, 5 per cent of net profits to educational fund, patronage dividends to shareholders, employees, and nonmembers at one-half the rate and may be credited on share of stock.

Annual reports: To commissioner of agriculture.

Provisions for existing organizations: Filing sworn statement with secretary of state.

Use of word "cooperative": Not to be used as part of name by any organization formed after passage of act unless act is complied with.

SOUTH DAKOTA.

Scope and purpose: Any agricultural, dairy, mercantile, mining, manufacturing, or mechanical business.

Number who may organize: Five or more.

Filing of amendments: With secretary of state.

Management: Not less than five directors. Officers shall be president, one or more vice presidents, secretary, and treasurer. The last two may be combined.

Stock ownership: Not more than \$1,000.

Purchasing of business of other associations: By a majority vote, not to exceed 25 per cent of its capital

Voting: Each member one vote.

Voting by mail: Permitted if vote is accompanied by a written copy of the question.

Distribution of earnings: May be revised by association, dividends on capital stock not to exceed 10 per cent, not less than 10 per cent of net profits to reserve fund until 30 per cent of paid-up capital is accumulated, not to exceed 5 per cent of net profits for educational fund, patronage dividend to shareholders.

Provisions for existing organizations: Filing sworn statement with secretary of state.

TENNESSEE.

Scope and purpose: Buying and selling any agricultural products and dealing in merchandise.

Number who may organize: Seven or more.

VIRGINIA.

Scope and purpose: Any agricultural, dairy, mercantile, manufacturing, or mechanical business.

Number who may organize: Five or more.

Filing of articles of incorporation: With judge of circuit court, State corporation commissioner, secretary of the commonwealth, and clerk of circuit or chancery court.

Filing fee: To secretary of commonwealth and clerk of court.

Management: Not less than three directors. Officers shall be president, one or more vice presidents, secretary, and treasurer. The last two may be combined.

Stock ownership: Not to exceed \$1,000.

Purchasing of business of other organizations: By majority vote, not to exceed 25 per cent of its capital.

Voting: Each member one vote.

Voting by mail: Permitted if vote is accompanied by a copy of the question.

Distribution of earnings: May be revised by association, stock dividends not to exceed 6 per cent, not less than 10 per cent of net profits to reserve until 30 per cent of paid-up capital stock is accumulated, 5 per cent of net profits for educational fund, patronage dividends to shareholders and employees and to nonshareholders at one-half rate.

Dissolution: If no stock dividends are paid for three successive years, five or more may apply to circuit court.

Use of word "cooperative": Not to be used as part of name by any organization formed after the passage of this act unless it complies with act.

WASHINGTON (NONSTOCK).

Scope and purpose: Any lawful purpose except carrying on of a business, trade avocation, or profession for profit.

Number who may organize: Five or more.

Filing of articles of incorporation: With secretary of state and county auditor of county in which principal place of business is located.

Filing fee: Same as for stock corporations.

Management: According to by-laws.

Capital stock: Nonstock.

Voting: All members have equal power.

Dissolution: Upon written request of two-thirds of the members.

Provisions for existing organizations: So deciding by a majority vote and filing statement with secretary of state and county auditor.

WASHINGTON (CAPITAL STOCK).

Scope and purpose: Any lawful business.

Number who may organize: Five or more.

Filing of articles of incorporation and amendments: With secretary of state and county auditor of county in which principal place of business is located.

Filing fee: \$25 to secretary of state and 15 cents per 100 words to auditor. For amendments, \$10 to secretary of state and 15 cents per 100 words to auditor.

Management: Not less than three directors. Officers shall be president, one or more vice presidents, secretary, and treasurer.

Issuance of stock: When paid for in full.

Stock ownership: Not more than one-fifth of stock.

Purchasing of business of other associations: By a majority vote of a majority of the stockholders.

Voting: Each member one vote.

Voting by mail: Permitted if accompanied by a written copy of the question.

Distribution of earnings: Capital stock dividends not to exceed 8 per cent, 10 to 25 per cent of remainder of net profits to reserve fund, patronage dividends to members, to nonmembers at one-half the rate to members.

Annual report: To secretary of state.

Provisions for existing organizations: Filing sworn statement with secretary of state.

Use of word "cooperative": Not to be used as part of name by any corporation not complying with this act.

WISCONSIN.

Scope and purpose: Any agricultural, dairy, mercantile, mining, manufacturing, or mechanical business.

Number who may organize: Five or more.

Filing of articles of incorporation and amendments: With secretary of state and the register of deeds of the county in which the principal place of business is located.

Filing fee: \$10 to secretary of state and 25 cents to register of deeds. For amendments, \$5 to secretary of state.

Management: Not less than five directors. Officers shall be president, one or more vice presidents, secretary, and treasurer. The last two may be combined.

Stock ownership: Not more than \$1,000.

Purchasing of business of other associations: By a majority vote, not to exceed 25 per cent of capital may be thus invested.

Voting: Each member one vote.

Voting by mail: Permitted if copy of question accompanies vote.

Distribution of earnings: Stock dividends not to exceed 6 per cent of net earnings to reserve fund until 30 per cent of paid-up capital stock is accumulated, 5 per cent of net profits to educational fund, patronage dividends to stockholders and employees and to nonstockholders at one-half rate.

Dissolution: If no profits are paid for five or more years, five or more stockholders may apply to circuit court.

Annual reports: To secretary of state.

Provisions for existing organizations: Filing sworn statement with secretary of state.

Use of word "cooperative": Not to be used as part of name by any corporation organized after passage of this act unless it complies with act.

WYOMING.

Scope and purpose: Agricultural, dairy, live stock, irrigation, horticultural, mercantile, manufacturing, or industrial business.

Number who may organize: Five or more.

Filing of articles of incorporation and amendments: With secretary of state and clerk of counties in which business is carried on.

Filing fee: Same as for general corporations.

Management: Not less than three directors.

Issuance of stock: When paid for in full.

Stock ownership: Not more than \$1,000 or one-third of outstanding stock.

Voting: Each member one vote.

Voting by mail or proxy: Not permitted unless provided in by-laws.

Distribution of earnings: May be revised by stockholders, not to exceed 8 per cent capital stock dividends, not less than 10 per cent of net earnings to reserve fund until 30 per cent of paid-up capital stock is accumulated, patronage dividends to non-members may be provided in by-laws.

Annual reports: Statement to be kept on file with the secretary of the association.

Use of the word "cooperative": Not to be used as part of the name unless this act is complied with.

THE CLAYTON AMENDMENT TO THE UNITED STATES ANTITRUST LAWS.

In preparing State laws authorizing cooperative organizations, consideration should be given to the United States antitrust laws, especially the amendment thereto commonly known as the Clayton amendment, which was passed by the Sixty-third Congress. Section

6 of this amendment has an important bearing on farmers' organizations because it exempts from the operation of the United States antitrust laws certain types of agricultural and horticultural organizations. Section 6 reads as follows:

That the labor of a human being is not a commodity or article of commerce. Nothing contained in the antitrust laws shall be construed to forbid the existence and operation of labor, agricultural, or horticultural organizations, instituted for the purposes of mutual help, and not having capital stock or conducted for profit, or to forbid or restrain individual members of such organizations from lawfully carrying out the legitimate objects thereof; nor shall such organizations, or the members thereof, be held or construed to be illegal combinations or conspiracies in restraint of trade, under the antitrust laws.

It is important that State laws authorizing cooperative corporations should be so framed or amended as to confer ample authority upon such organizations to comply with the provisions of the Federal statute.

Investigation shows that many farmers' organizations operate on the capital stock plan because the laws of the State under which they exist require capital stock, although a majority of them choose the capital stock plan because it is thought that such a plan is best adapted to securing the necessary capital for financing them. The legal difficulties under existing State laws for noncapital stock organizations should be eliminated as their presence influences the creation of capital stock organizations which as a matter of law can never possess the benefits and privileges conferred by section 6.

The sentiment in the public mind that capital stock is essential for the procurement of necessary capital, while widespread, is not well founded, as is demonstrated by the success and great borrowing capacity of various noncapital stock cooperative organizations in existence in the United States at the present time.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 548

Office of the Secretary
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief



Washington, D. C.

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THE BUSINESS OF TEN DAIRY FARMS IN THE BLUEGRASS REGION OF KENTUCKY.

By J. H. ARNOLD, *Agriculturist.*

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The purpose of this bulletin is to present a brief analysis of the business of 10 dairy farms which were found among 187 farms¹ selected and studied during 1914 in Mason, Scott, and Madison Counties, in the bluegrass region of Kentucky. This analysis will show how these farms were organized and will point out the factors which made some of them profitable. From so few records it would not be possible to analyze thoroughly the economic situation relative to dairying in this locality, but the analysis should be of some practical interest to the bluegrass farmer who already is running a dairy farm or who is about to organize one.

GENERAL DESCRIPTION OF THE REGION FROM THE POINT OF VIEW OF DAIRYING.

The fact that this locality is famous for bluegrass would suggest a favorable locality for dairying. The adaptation of the soil to bluegrass pasture is the distinctive natural advantage which this locality has for this type of farming. The climatic factors, however, partly

¹ An analysis of these farms, including the 10 dairy farms, is given in U. S. Department of Agriculture Bulletin No. 482, Farming in the Bluegrass Region.

offset this advantage, especially for the production of cheese and butter. The long summer months are warm, with a lower rainfall than the winter months, while in the extensive dairy sections of Wisconsin and New York the highest rainfall is during the summer months, which average 7 to 8 degrees cooler than in Kentucky. These adverse conditions have not interfered with the increased production of market milk where there is a demand at good prices, but they are a handicap especially in the production of cheese, which is produced to best advantage in a climate that is relatively cool.

Most of the dairy farms in the region have developed near such large cities as Cincinnati and Louisville, where large quantities of milk and cream may be marketed. Lexington, a city of about 40,000 inhabitants, and several other towns of 5,000 to 15,000, furnish a market for a few dairy farms in the central part of the bluegrass region.

RECEIPTS FROM DAIRY PRODUCTS, TOGETHER WITH LABOR INCOMES, ON EACH OF TEN FARMS.

The business of each of the 10 farms studied may be summarized briefly, as follows:

TABLE I.—*Size of farms, with number of cows and with receipts from labor income and dairy products.*

Farm No.	Size of farm.	Number of cows.	Labor income.	Gross receipts from milk.	Receipts from cream.	Receipts from butter.	Gross receipts per cow.
1.....	400	75	\$1,466	\$5,315	\$2,101	.....	\$98.88
2.....	290	30	3,654	4,500	.....	.....	150.00
3.....	247	19	1,739	3,066	730	.....	199.78
4.....	150	50	6,408	6,768	1,128	\$25	158.00
5.....	51	15	3,201	2,920	225	260	227.00
6.....	86	9	1,121	76	1,996	.....	230.00
7.....	82	30	1,509	2,966	480	.....	114.86
8.....	70	4	¹ 0	.....	208	.....	52.00
9.....	134	12	287	.....	624	.....	52.00
10.....	120	12	² 0	.....	104	780	73.60
Average of all.....	163	27	1,773	2,561	689	106	126.16

¹ This farm fell \$139 short of paying expenses, including interest on investment.

² This farm fell \$1,521 short of paying expenses, including interest on investment.

Thus it will be seen that these ten dairy farms depend mostly on market milk for income. Cream is next in importance. Very little butter is marketed. The one dairyman depending mostly on butter for income failed to make expenses, counting interest on investment among the expenses. The market price of milk distributed to customers ranged from 7 to 10 cents per quart, and cream 60 cents to \$1 per gallon, depending on market opportunities and quality of

product. Near the smaller towns the milk is mostly bottled and is marketed at the door of the customer. In the vicinity of larger cities it is mostly shipped in and retailed through local distributors. When this was done the farmer received 15 to 20 cents per gallon for milk and paid $1\frac{1}{2}$ to 2 cents per gallon to ship it 30 to 50 miles.

The labor incomes¹ on most of the farms were large, as compared with those of successful farms of other types in this region. The average labor income on 187 farms was \$750, while the average of these ten dairy farms was \$1,773.

Table I shows plainly that of the ten farms studied those which sold market milk and which had high net receipts per cow made the most money.

OTHER SOURCES OF INCOME.

While dairy products furnished the main source of income on these farms, the farmers found it profitable to diversify to some extent. Other common sources of income were tobacco and wheat. In some cases a few steers were kept. There was some income from the sale of dairy cows, young stock, and calves. In some cases also there was a substantial income from swine and poultry. The percentage receipts from dairy products and tobacco on these farms were as follows:

TABLE II.—*Percentage receipts from dairy products and tobacco.*

Farm No.	Receipts from dairy.	Receipts from tobacco.	Farm No.	Receipts from dairy.	Receipts from tobacco.
	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
1.....	80	10	7.....	90	0
2.....	67	13	8.....	55	0
3.....	82	2	9.....	49	15
4.....	72	0	10.....	51	0
5.....	85	9			
6.....	80	9	Average.....	71	5.8

Tobacco is a crop specially adapted to the region, and on many farms it is the main source of income. The percentage receipts from dairying on the ten farms in question, as shown in Table II, included net receipts from dairy stock and from calves. During the past two years (1915 and 1916) Farm No. 4 has found hemp a profitable crop, not only because of recent increase in price of this product, but because during its growing season hemp requires no attention, while the harvesting is done in a few days by machinery and the other operations in preparation for marketing may be let out to negroes who are experienced hemp workers.

¹ Labor income is what the farmer makes above expenses, which include current interest on the money he has tied up in his business.

COST OF FEED.

As previously suggested, the adaptation of soil to bluegrass grazing is a distinct advantage for the dairy business in this section. During the grazing period, from May to November, most of these dairymen have not fed concentrates, except when the season happened to be drier than usual and the pasture short. Milk usually is reduced in price during the summer because of the plentifulness of grazing, which increases the general supply of milk. Cows graze to a considerable extent on bluegrass during the winter months, and occasionally on rye or wheat fields. Thus the quantity of feed that needs to be bought is small, compared with that bought on the Northern dairy farm. On account of recent advance in price of concentrated feeds, one of the ten dairymen has filled his old silo with clover and has built a new one for corn and cane silage. Clover is thus used as a substitute for the more expensive concentrated feeds, such as cottonseed meal, bran, and shorts. In 1914, the year the business records of these farms were taken, the average cost of concentrated feeds bought was about \$14 per cow, which in terms of concentrated feed at \$35 per ton (about the average price in 1914) would mean that the average cow got about 4.4 pounds of this feed daily for 180 days. Other purchased feeds, mostly hay and corn fodder, amounted on the average to about \$4.50 per cow.

The bluegrass dairyman pastures more intensively than the average live-stock farmer. The latter allows about 4 acres for each animal unit,¹ while the average for the ten dairy farms was found to be about 1.6 acres for each animal unit on the farm. Dairy farms are relatively small, the manure is exceptionally rich in plant food, and a large part of it is scattered on the pastures. According to figures obtained, \$40 to \$50 would be a liberal estimate for the average cost of feed for each dairy cow kept on the farms studied.

TO WHAT EXTENT DAIRYING MAY BE DEVELOPED IN THE BLUEGRASS REGION.

While a study of these ten dairy farms would indicate that market milk production was profitable where markets have developed, dairy farming is not the type that can be as generally recommended as some other types until it has been demonstrated that butter and cheese, the least perishable of dairy products, and those which have a wide demand in the general market, can be profitably produced here. The production of milk and butter in the three counties (Madison, Scott, and Mason) in which these ten dairy farms are located remained practically stationary between 1890 and 1910. On

¹ Animal unit—the equivalent of 1 cow, horse, or beef animal. Two heifers, 4 calves, 7 sheep, 5 hogs, 14 pigs, or 100 chickens are counted as equivalent to an animal unit.

the other hand, the production of tobacco, hemp, hay, beef cattle, and sheep, characteristic of the more general profitable types, had a marked increase during the same period. In 1890 the census enumerators found 5,357 pounds of cheese produced in Madison County and 2,025 pounds in Mason County. In the census years of 1900 and 1910, practically none was reported for these counties. In Jefferson County, bordering on the bluegrass region, 10,120 pounds was reported in 1890 and 13,817 pounds in 1900. None, however, was reported in the census of 1910. Three counties bordering Jefferson produced about 15,000 pounds during the period covered by the census of 1890 and 1900, but none was reported for these counties in 1910. Between 1900 and 1910, however, there was a large increase in the production of market milk for the Louisville market in these counties. The cheese production that still persists in Kentucky is confined largely to the low mountains and hills bordering the bluegrass region, known as "The Rim," where there is some bluegrass land, though rather unfavorable for general farming and low in price. In this region spring water is abundant and the climate is somewhat cooler than in the more level bluegrass country. On the hilly, cheaper land along the Ohio River a small quantity of cheese was still being produced in 1910.

These facts relative to dairying in Kentucky emphasize the truth that farm enterprises once started in a locality will develop only to the extent that they find a favorable environment and are found to be profitable by practical farmers. The production of butter and cheese would no doubt be profitable in the bluegrass region and possibly at the present time would be a thriving industry if other enterprises such as tobacco, hemp, wheat, beef cattle, swine, and sheep had not proved to be more generally profitable. The fact, however, that the production of butter and cheese has not yet developed into a profitable and extensive business here is not conclusive evidence that it would not be profitable on many farms favorably situated for these enterprises. Even on many general diversified farms in this region profits could be increased by keeping better dairy cows and producing butter and even some cheese as a side line. Many farms in the bluegrass region have excellent springs which may be used to advantage in connection with such enterprises.

An important factor in retarding the development of the dairy industry even under favorable conditions is the general reluctance of bluegrass farmers to engage in it. While negro laborers as a rule are experts in growing and handling tobacco, they are not familiar with the processes of dairying and share the common objection to it. In some sections, however, where dairying has become profitable and where it has been practiced a long time, this dislike is being gradually overcome.

SEVEN SUCCESSFUL DAIRY FARMS ANALYZED AND COMPARED.

FARM NO. 1.			
Size of farm.....	acres..	400	
Number of cows.....		75	
Number of other animal units ¹		37	
Total capital ²		\$50,097	
Working capital ³		7,874	
Total receipts.....		11,824	
Receipts from dairy.....		7,416	
Expenses ⁴		7,854	
Farm income ⁵		3,970	
Labor income ⁶		1,466	

This is the largest farm of the ten in question and is valued at \$125 per acre. It is well situated near a market point. While it is somewhat rolling, the soil is of good quality and about all of it tillable. If properly organized, this farm should have made the largest labor income of the group. Instead, it is among the lowest, those which were only fairly successful. In the first place, the dairy business shows up poor in quality, receipts per cow being low as compared with those of the more successful farms. The operator has 75 cows, about as many as he can give proper attention to. Half his acreage easily could be made to support this herd. Thus, this area of land (400 acres) might be supporting two successful dairy farms instead of one (see farm No. 4). If there were an additional farm superintendent, however, the farm might be so organized that the dairy business could be conducted as one department, while the greater part of the land could be cropped in accordance with the best practice in the section. With a higher degree of diversity and by handling other live stock, the gross income of this farm, even with its present management, should be increased considerably without much more expense. The average expenses of the ten farms are about 45 per cent of receipts, while on this farm they are about 75 per cent, showing that the business was too expensive for the income received. This farmer housed his cows in a \$7,000 dairy barn, an investment of nearly \$100 per cow, while his nearest competitor, one of the most successful farmers of the group, had but one-third of this amount invested. Although this was a large farm and showed a relatively small proportion of its receipts from other sources than dairying, it failed to produce as much feed for dairy stock as the average farm (\$18) and expended for purchased feeds \$20 per cow.

¹ See footnote, p. 4.

² Total capital includes investment in land, buildings, machinery, live stock, feed, supplies, and cash to run the business.

³ Working capital includes all items of capital except land, buildings, and other improvements usually included in real estate.

⁴ Expenses include a charge for unpaid family labor, depreciation, and 5 per cent interest on total capital besides money actually paid out in conducting the farm business.

⁵ Farm income is the total receipts less expenses.

⁶ Labor income is farm income less 5 per cent interest on invested capital.

FARM NO. 2.

Size of farm.....	acres..	290
Number of cows.....		30
Number of other animal units.....		28
Total capital.....		\$26,890
Working capital.....		6,881
Total receipts.....		8,383
Receipts from dairy.....		4,500
Expenses.....		3,385
Farm income.....		4,998
Labor income.....		3,654

Of the larger sized farms among the ten studied this one is the most efficiently organized. The diversity is much greater than that of farm No. 1. About 46 per cent of receipts were from sources other than dairying, mainly wheat and tobacco. Sales of live stock amounted to \$1,200 above purchases. The operator owned 132 acres and rented 158 additional, for which he paid \$800 a year. All the feed except concentrates was raised on the farm. Only one man was hired, the operator and his family doing most of the dairy work. The manure from the dairy was applied to his own land. This made his crop yields much higher than the average. Eleven acres of tobacco and 10 acres of corn were raised by a cropper. Thirty-three acres of corn for grain, 12 acres of silage corn, 50 acres of wheat, 25 acres of meadow hay, and 5 acres of tobacco were raised by his own and hired labor. The owner had been in the dairy business about 40 years and is about 60 years of age. A large family had been raised and educated.

FARM NO. 3.

Size of farm.....	acres..	247
Number of cows.....		19
Number of other animal units.....		16
Total capital.....		\$15,396
Working capital.....		3,046
Total receipts.....		5,105
Receipts from dairy.....		3,796
Expenses.....		4,438
Farm income.....		2,509
Labor income.....		1,739

This farm had 10 acres of corn for grain, 8 acres for silage, 10 acres in rye which was grazed, and 20 acres in hay. There were 153 acres in pasture, 2 acres in garden and orchard, and the remainder, 44 acres, was considered waste land. The topography was hilly and not well adapted to cultivated crops. The land was valued at \$40 per acre, though the more level land in the community was valued at \$100 to \$150 per acre. Three year-hands were employed on this farm and seven head of work stock were kept. Both man-labor and horse-labor were poorly utilized. A better utilization could have been achieved and the income considerably increased if a few acres of

tobacco had been raised. There were no receipts from crops and diversity was low.

FARM NO. 4.

Size of farm.....	acres..	150
Number of cows.....		50
Number of other animal units.....		48
Total capital.....		\$33,081
Working capital.....		11,354
Total receipts.....		12,500
Receipts from dairy.....		7,921
Expenses.....		2,818
Farm income.....		8,062
Labor income.....		6,408

This farm well may be classed as the best dairy farm of the ten. While the receipts per cow were considerably above the average, others had higher receipts per cow, but in the expenses this farm showed high efficiency in the economy of labor and feed, two most important factors in expenses. Operating expenses were only about 35 per cent of receipts, as compared with 45 per cent, the average for the ten farms. The land area (150 acres) was small as compared with the number of stock units kept on the farm. These number about 98, or about 1.9 acres for each animal unit. Of this number of animal units, 50 were dairy cows. Every part of the farm, including pasture area, received frequent applications of stable manure. There is practically no waste land on this farm. But a small acreage is occupied by fences, buildings, and roadway. Bluegrass grows even in small lots and about the buildings. The feed purchased amounted to about \$10 per cow. About 50 per cent of the farm area is in bluegrass pasture, which in a normal season furnishes all the feed for dairy stock during the summer. A considerable amount of grazing also is done during the winter. Fields that are to be pastured in winter are allowed to accumulate a good growth of grass in the fall. About \$1,000 of the total receipts represented breeding fees. Usually a few acres of tobacco are raised. During the last two years (1915-1916), however, hemp has been substituted for tobacco. It was estimated that the hemp for 1916 would yield about 1,700 pounds per acre, which, at 10 cents per pound (about the price of the previous year), would be \$170 per acre. The expense of growing an acre of hemp is about the same as that of tobacco (\$50 to \$60, exclusive of rent), and the average rent for the land is figured at \$30 to \$50 per acre.

This farm has been organized as a dairy farm for about 12 years and has been exceptionally successful. It sets the standard for quality and prices for milk in the locality and is rated among the best dairy farms in the State. The operator is a graduate of an agricultural college. He does the work of milking, bottling, and distributing with the help of a man and a boy.

FARM NO. 5.

Size of farm.....	acres..	51
Number of cows.....		15
Number of other animal units.....		11
Total capital.....		\$8,843
Working capital.....		2,786
Total receipts.....		5,449
Receipts from dairy.....		3,405
Expenses.....		1,811
Farm income.....		3,638
Labor income.....		3,196

This farm shows the possibility of profitable dairying on a small farm with a small amount of capital invested, and on which about all the labor is done by the operator and his family. Here, again, high business efficiency was shown in that operating expenses were but 33 per cent of receipts and the labor income was among the highest of the group. This farmer has to buy more than the usual quantity of feed, which cost him about \$25 per cow. The receipts per cow were unusually high. This was due, no doubt, to high quality of cows kept and to the fact that he milked the cows himself. The milk was retailed at 8 to 10 cents per quart and the cream at \$1 per gallon. This farmer raised $3\frac{1}{2}$ acres of tobacco, which he sold for about \$500. He sold 5 cows for \$55 per head and bought better ones for \$65 per head. Sales from poultry were \$80, and a colt was raised which increased in value \$115. This farmer has been a farm laborer 7 years, a tenant 10 years, and an owner 8 years. He is now 40 years old. He owns 40 acres and rents 11 acres additional for hay. Twenty-five acres were devoted to permanent bluegrass pasture; the remainder, besides 2 acres counted as waste, were in crops.

FARM NO. 6.

Size of farm.....	acres..	86
Number of cows.....		9
Number of other animal units.....		33
Total capital.....		\$16,800
Working capital.....		2,675
Total receipts.....		2,982
Receipts from dairy.....		2,072
Expenses.....		1,021
Farm income.....		1,961
Labor income.....		1,121

This farm was only moderately successful. Profits could have been increased greatly if the business had been made larger by increasing the income from cows. If the operator had hired a man he could have increased his herd to 20 or 25 cows and besides could have raised 5 to 6 acres of tobacco instead of 2. There were no receipts from hogs, although there must have been a large quantity of skim milk which should have been fed on the farm. Only \$75 worth of

skim milk was sold, showing that much of it must have gone practically to waste.

FARM NO. 7.

Size of farm.....	acres..	82
Number of cows.....		30
Number of other animal units.....		30
Total capital, owner and tenant.....		\$13,661
Working capital, owner and tenant.....		3,396
Tenant's capital.....		1,698
Total receipts.....		5,134
Receipts from dairy.....		3,446
Expenses.....		2,032
Farm income, owner and tenant.....		3,102°
Tenant's farm income.....		1,594
Tenant's labor income.....		1,509
Owner's profit on investment.....	per cent..	12.6

This farm was operated by a tenant who had a half interest in the working capital of the farm, which included the investment in machinery, live stock, feed, and supplies, and cash to run the business. Business expenses were shared equally, as were also receipts. The tenant with the help of two year-hands and some extra labor performed the work. There were three work horses. Forty-five acres of the farm were in corn for silage, 33 acres in pasture, 2 acres waste, and 1 acre for garden. Receipts from other sources than dairy cows were mainly from young stock. There were no receipts from crops.

THE FARMS THAT FAILED.

The three unprofitable farms of the ten were inefficiently organized and operated. Apparently these farmers depended mainly on dairy products for an income; but as they did not stock their farms with enough cows to make it worth while to spend their time at dairying, there could be no other result than failure. This is strikingly true of farm No. 8, which could not be classed as a dairy farm except on the ground that the four cows kept were the main source of income. These farms kept no regular hired laborers and a very small amount of extra labor was hired.

About the only comment that can be made upon these farms is that the operators were wasting their opportunities. They had fair-sized farms, but each was operating a small-sized business. The quality of the cows was poor, as shown by receipts, and no doubt much of the milk was wasted. The usual bluegrass farm in this section keeps from two to eight cows to supply milk to the family and laborers. It does not pay a farmer to give special attention to the dairy business unless there are a sufficient number of cows to warrant special equipment and the application of most of his time. He must develop and maintain a profitable market. If cream or

butter is sold, the skim milk and buttermilk, if not sold, should be utilized profitably by feeding it to hogs.

COMPARISON OF THE SEVEN MORE SUCCESSFUL DAIRY FARMS WITH THE AVERAGE OF TEN.

It may be helpful to compare the average of the seven successful dairy farms with the average of the whole group of ten, with respect to the more essential factors, as shown below:

	Average of ten farms.	Average of the seven successful farms.
<i>Distribution of crops:</i>		
Average size of farm.....acres..	163	187
In crops.....do.....	66	70
In pasture.....do.....	76	100
In corn for grain.....do.....	15	10
In corn for silage.....do.....	13	16
In wheat.....do.....	13	15
In meadow.....do.....	16	20
In tobacco.....do.....	5	6
In miscellaneous.....do.....	4	3
<i>Distribution of live stock:</i>		
Dairy cows.....number..	27	40
Young stock.....do.....	21	16
Swine.....do.....	29	25
Poultry.....do.....	184	183
<i>Distribution of capital:</i>		
Total capital invested.....	\$22, 552	\$23, 622
Total working capital.....	4, 764	5, 286
Machinery.....	711	771
Investment in live stock.....	3, 291	3, 699
Cash to run farm.....	405	420
Feed and supplies.....	355	366
<i>Distribution of receipts:</i>		
Live-stock products.....	3, 554	4, 610
Live-stock inventory and sales.....	1, 048	1, 035
Crop receipts.....	589	813
Miscellaneous.....	120	235
Total.....	5, 301	6, 693
<i>Profits:</i>		
Receipts per cow.....	126	164
Average farm income.....	3, 149	4, 266
Average labor income.....	1, 773	2, 954
Per cent net earnings on investment ¹	10	14

¹ Per cent net earnings is obtained by dividing the farm income (less the value of operator's labor and management) by the total farm investment. The average of operator's labor and management on the ten farms as estimated by the farmer was \$766; on the seven most successful, \$866.

These comparisons illustrate many of the points discussed in the foregoing pages relative to the successful dairy farms. For instance, the average successful farm had the largest business, as shown by the

size of farm, the number of dairy cows, and the working capital. On the average successful farm there were more receipts from crops and miscellaneous sources than were shown for the average of the ten farms. This indicates the greater degree of diversity on the successful farms. The most important comparison is that shown for the receipts per cow. It will be noticed that the average successful farm had much higher receipts per cow—\$164, as compared with \$126 on the average of the ten.

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HENRY S. GRAVES, Forester

Washington, D. C.



May 5, 1917

CROSSTIES PURCHASED AND TREATED IN 1915.

By ARTHUR M. MCCREIGHT, *Office of Industrial Investigations.*

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CROSSTIES PURCHASED, 1915.

Purchases of crossties were smaller in 1915 than in other years. The total number bought by all classes of purchasers was approximately 121,402,611. The inquiry covered steam railroads, electric railways, and light, heat, and power companies. No attempt was made to determine the prices paid for crossties, or the number of ties laid in new track, or to show separately the number of hewed and sawed ties purchased.

The information was obtained by the Forest Service entirely by means of correspondence; and the total number of ties reported by the purchasers of all classes who sent the information requested was 97,106,651. The estimated total of all purchases was obtained in the following manner: The actual number reported by steam railroads was 88,498,655. The mileage of roads so reporting amounted to 78.46 per cent of the total mileage of the country. Assuming that the nonreporting roads made purchases in proportion to their mileage, or 24,295,960 ties, the total for all steam railroads amounted to 112,794,615. To this is added the number purchased by electric railways and light, heat, and power companies, or 8,607,996, and the grand total for 1915 is estimated to be 121,402,611.

Table 1 shows the number of crossties purchased each year from 1907 to 1911, and for the year 1915, classified according to kinds of wood and arranged in the order of number purchased during 1915. The smallest number of ties reported purchased for any year since 1907 was in 1915. The figures in the table for 1911 and previous years were taken from reports prepared in cooperation with the Bureau of the Census. Statistics were not obtained for the years 1912, 1913, and 1914.

Five kinds of wood supplied over 81 per cent of the total number of ties reported purchased in 1915. These were the oaks, southern pine, Douglas fir, cedar, and chestnut.

While there seems to be no trend toward the use of any one species, more oak was reported than any other kind of wood. This is doubtless due to the fact that oak has the requisite strength and hardness for ties and is available in many localities in large quantities. White oak is also desirable because of its durability, and red oak because satisfactory preservative treatment can be given it. Oak, including both red and white, supplied 49,333,881 ties, or 50.8 per cent of the total number reported purchased.

Yellow pine was second in importance, contributing 14,115,681 ties, or 13.43 per cent of the total number reported. This species is largely used because of its availability and cheapness, and, in the case of longleaf pine, its durability; the strength of longleaf pine adds to its desirability. Shortleaf and loblolly pine do not make altogether satisfactory ties, but are used largely because they are relatively cheap and take a satisfactory preservative treatment.

TABLE 1.—*Number of crossties reported purchased, 1907 to 1911 and 1915, by kinds of wood.*

Kind of wood.	1915	1911	1910	1909	1908	1907
All kinds.....	¹ 97,106,651	135,053,000	148,231,000	123,751,000	112,466,000	153,703,000
Oak.....	49,333,881	59,508,000	68,382,000	57,132,000	48,110,000	61,757,000
Southern pine.....	14,115,681	24,265,000	26,264,000	21,385,000	21,530,000	34,215,000
Douglas fir.....	6,950,910	11,253,000	11,629,000	9,067,000	7,988,000	14,525,000
Cedar.....	5,122,103	8,015,000	7,305,000	6,777,000	8,172,000	8,954,000
Chestnut.....	4,548,352	7,542,000	7,760,000	6,629,000	8,074,000	7,851,000
Cypress.....	4,478,612	5,857,000	5,396,000	4,589,000	3,457,000	6,780,000
Eastern tamarack.....	2,606,794	4,138,000	5,163,000	3,311,000	4,025,000	4,562,000
Western yellow pine.....	1,402,836	2,696,000	4,612,000	6,797,000	3,093,000	5,019,000
Lodgepole pine.....	1,316,819					
Western larch.....	1,251,304					
Beech.....	1,173,490	1,109,000	798,000	195,000	192,000	52,000
Maple.....	1,069,547	1,189,000	773,000	158,000	151,000	
Hemlock.....	859,662	3,686,000	3,468,000	2,642,000	3,120,000	2,367,000
Redwood.....	563,685	1,820,000	2,165,000	2,088,000	871,000	2,032,000
Gum.....	485,466	1,293,000	1,621,000	378,000	262,000	15,000
Birch.....	465,815					
All other.....	1,361,694	2,682,000	2,895,000	2,603,000	3,421,000	5,574,000

¹ Mileage of railroads reporting ties represent 78.46 per cent of total mileage. Mileage represented for former years not obtainable.

Individual quantities were not given for the number of western larch, lodgepole pine, and birch ties reported prior to 1915. It is probable that the figures for western yellow pine included those of lodgepole pine in former years. Larch might also have been tabulated with the tamarack statistics. In 1915 the number of lodgepole pine and western larch ties purchased was over a million each.

Table 2 shows the number of crossties reported purchased by the steam railroads, electric railways, and light, heat, and power companies. The total number of crossties reported purchased during 1915 by the steam railroads was 88,498,655, or 91.13 per cent of the total reported by all classes of purchasers. White and red oak and south-

ern pine furnished the greater part of these, although Douglas fir and cedar were reported in large quantities.

The number of ties purchased by the electric railways and light, heat, and power companies amounted to 8.87 per cent of the total, a decrease of 281,000 ties in comparison with the number purchased by these companies in 1911. The greater part of those reported were white oak, cedar, and chestnut. Southern pine and red-oak ties were purchased in nearly the same quantities, while fewer birch ties than any other were separately reported.

TABLE 2.—*Number of crossties reported purchased in 1915, by classes of purchasers and kinds of wood.*

Kind of wood.	Total.	Steam railroads representing 78.46 per cent of entire mileage in the United States.	Electric railways, and light, heat, and power companies.
All kinds.....	97, 106, 651	88, 498, 655	8, 607, 996
White oak.....	32, 461, 555	30, 160, 316	2, 301, 239
Red oak.....	16, 872, 326	15, 989, 605	882, 721
Southern pine.....	14, 115, 681	13, 226, 654	889, 027
Douglas fir.....	6, 950, 910	6, 308, 635	642, 225
Cedar.....	5, 122, 103	4, 121, 570	1, 000, 533
Chestnut.....	4, 548, 352	2, 666, 402	1, 881, 950
Cypress.....	4, 478, 612	4, 375, 012	103, 600
Eastern tamarack.....	2, 606, 794	2, 520, 475	86, 319
Western yellow pine.....	1, 402, 836	1, 183, 535	219, 301
Lodgepole pine.....	1, 316, 819	1, 254, 420	62, 399
Western larch.....	1, 251, 304	1, 196, 415	54, 889
Beech.....	1, 173, 490	1, 139, 457	34, 033
Maple.....	1, 069, 547	1, 062, 086	7, 461
Hemlock.....	859, 662	839, 924	19, 738
Redwood.....	563, 635	270, 694	292, 991
Gum.....	485, 466	485, 466	.....
Birch.....	465, 815	462, 462	3, 353
All other.....	1, 361, 694	1, 235, 477	126, 217

Table 3 shows the number of crossties reported purchased by the steam railroads, representing 78.46 per cent of the total mileage of the country, classified by regions which are the same as those used by the Interstate Commerce Commission.

The eastern region comprises that portion of the United States bounded on the west by the northern and western shores of Lake Michigan to Chicago, thence by a line to Peoria, thence to East St. Louis, and down the Mississippi River to the mouth of the Ohio River. It is bounded on the south by the Ohio River from its mouth to Parkersburg, W. Va.; thence down the Potomac River to its mouth. This region is second in size of the three regions and has a total of 64,491 miles of railroad. The actual mileage of the reporting railroads is 43,018 miles, or 66 per cent of the total mileage of the region.

The southern region is that portion of the United States bounded on the north by the eastern region and on the west by the Mississippi River. It is the smallest of the three regions and has a total of

49,670 miles of railroads. The mileage of the reporting railroads was 35,830 miles, or 72 per cent of the total mileage of the region.

The western region, which is the largest, is the remainder of the United States and has a total of 141,936 miles of railroads. The mileage of the reporting railroads is 122,432 miles, or 86 per cent of the total of the region.

White oak is the predominating wood in all regions. It is very evenly distributed throughout them all; and the southern and eastern regions reported practically the same quantities. Practically all of the red-oak ties were reported in the western and eastern regions, the southern region reporting only 512,054. Southern pine is rather evenly distributed through all the different regions.

Oak, Douglas fir, and southern pine meet the greater part of the demand in the western region, although cypress, cedar, tamarack, western yellow pine, and lodgepole pine are well represented.

The eastern region draws largely upon oak, southern pine, cedar, and chestnut for its crossties. These four species supplied 27,681,334, or 92 per cent of the total number of ties purchased in this region. Douglas fir was purchased in small quantities, the total being 2,491 ties.

In the southern region, white oak, southern pine, and cypress contributed 16,096,815 ties, or 90 per cent of the total purchased in the region. There were reported 432 hemlock crossties and only 27 cedar ties. Beech and maple were reported in nearly equal quantities.

TABLE 3.—*Number of crossties reported purchased in 1915 by steam railroads, representing 78.46 per cent of total mileage, by regions and kinds of wood.*

Kind of wood.	Total.	Western region.	Eastern region.	Southern region.
All kinds.....	88,498,655	40,650,424	30,007,583	17,840,648
White oak.....	3,160,316	11,227,462	9,336,366	9,596,488
Red oak.....	15,989,605	5,630,237	9,797,314	512,054
Southern pine.....	13,226,654	4,692,350	3,922,080	4,612,224
Douglas fir.....	6,308,685	6,306,194	2,491	.....
Cypress.....	4,375,012	2,467,158	19,751	1,888,103
Cedar.....	4,121,570	2,004,822	2,116,721	27
Chestnut.....	2,666,402	96,443	2,508,853	61,103
Eastern tamarack.....	2,520,475	2,408,642	111,833	.....
Lodgepole pine.....	1,254,420	1,254,420	.....	.....
Western larch.....	1,196,415	1,196,415	.....	.....
Western yellow pine.....	1,183,535	1,145,371	3,364	34,800
Beech.....	1,139,457	118,363	648,774	372,320
Maple.....	1,062,086	111,400	578,373	372,313
Hemlock.....	839,924	811,822	27,670	432
Gum.....	485,466	275,741	208,550	1,175
Birch.....	462,462	194,801	267,661	.....
Redwood.....	270,694	270,694	.....	.....
All other.....	1,235,477	398,089	457,782	389,606

Table 4 indicates the number of crossties purchased by the various classes of railroads. Class I roads are those whose annual operating revenues are over \$1,000,000; Class II, from \$100,000 to \$1,000,000; and Class III, under \$100,000. The railroads in Class I represent 183,493 miles; those in Class II and Class III represent 9,587 miles

and 8,200 miles respectively. The total mileage of the reporting railroads in these three classes is 201,280 miles, or 78.46 per cent of the total mileage of the steam railroads in the United States. The mileage of the reporting railroads in Class I constitutes over 71 per cent of the entire mileage of the country. It is also over 80 per cent of the mileage of Class I roads.

TABLE 4.—*Number of crossties reported purchased in 1915 by steam railroads, representing 78.46 per cent of total mileage in all regions by classes and kinds of wood.*

Kind of wood.	Total.	Class I.— Operating revenues, over \$1,000,000.	Class II.— Operating revenues, \$100,000— \$1,000,000.	Class III.— Operating revenues, under \$100,000.
All kinds.....	88,498,655	81,362,505	3,641,978	3,494,172
White oak.....	30,160,316	27,557,928	1,321,443	1,280,945
Red oak.....	15,989,605	15,495,614	166,023	327,968
Southern pine.....	13,226,654	11,697,745	877,836	651,073
Douglas fir.....	6,308,685	5,964,527	212,991	131,167
Cypress.....	4,375,012	3,934,789	256,282	183,941
Cedar.....	4,121,570	3,672,564	202,126	246,880
Chestnut.....	2,666,402	2,323,586	117,722	225,094
Eastern tamarack.....	2,520,475	2,390,333	91,799	38,343
Lodgepole pine.....	1,254,420	1,201,347	23,340	29,733
Western larch.....	1,196,415	1,136,944	36,874	22,597
Western yellow pine.....	1,183,535	1,057,841	10,010	115,684
Beech.....	1,139,457	1,096,095	15,884	27,478
Maple.....	1,062,086	1,021,603	13,719	26,764
Hemlock.....	839,924	650,774	128,475	60,675
Gum.....	485,466	475,263	904	9,299
Birch.....	462,462	455,881	6,581	-----
Redwood.....	270,694	162,184	67,212	41,298
All other.....	1,235,477	1,067,487	92,757	75,233

Tables 5, 6, and 7 show the number of crossties purchased by the steam railroads in the western, eastern, and southern regions of the country. They are tabulated according to the three classes of roads and the species are arranged in the order of number of ties purchased.

TABLE 5.—*Number of crossties reported purchased in 1915 by steam railroads representing 86.54 per cent of the mileage in the western region, by classes of railroads and kinds of wood.*

Kind of wood.	Total.	Class I.— Operating revenues, over \$1,000,000.	Class II.— Operating revenues, \$100,000— \$1,000,000.	Class III.— Operating revenues, under \$100,000.
All kinds.....	40,650,424	37,425,087	1,775,397	1,449,940
White oak.....	11,227,462	10,027,038	602,737	597,687
Red oak.....	5,680,237	5,516,065	62,178	101,994
Douglas fir.....	6,306,194	5,964,527	210,500	131,167
Southern pine.....	4,692,350	4,345,555	176,836	169,959
Cypress.....	2,467,158	2,303,909	148,352	14,897
Eastern tamarack.....	2,408,642	2,334,141	46,346	28,155
Cedar.....	2,004,822	1,716,987	191,099	96,736
Lodgepole pine.....	1,254,420	1,201,347	23,340	29,733
Western larch.....	1,196,415	1,136,944	36,874	22,597
Western yellow pine.....	1,145,371	1,057,841	10,010	77,520
Hemlock.....	811,822	633,277	121,686	56,859
Gum.....	275,741	267,563	704	7,474
Redwood.....	270,694	162,184	67,212	41,298
Birch.....	194,801	194,801	-----	-----
Beech.....	118,363	112,363	-----	6,000
Maple.....	111,400	103,417	1,137	6,846
Chestnut.....	96,443	92,944	-----	3,499
All other.....	388,089	354,184	76,386	57,519

TABLE 6.—*Number of crossties reported purchased in 1915 by steam railroads representing 66.24 per cent of the mileage in the eastern region, by classes of railroads and kinds of wood.*

Kind of wood.	Total.	Class I.— Operating revenues, over \$1,000,000.	Class II.— Operating revenues, \$100,000— \$1,000,000.	Class III.— Operating revenues, under \$100,000.
All kinds.....	30,007,583	28,365,491	615,807	1,026,285
Red oak.....	9,797,314	9,511,011	77,926	208,377
White oak.....	9,336,366	8,810,429	308,817	221,120
Southern pine.....	3,922,080	3,727,961	22,315	171,804
Chestnut.....	2,508,853	2,201,641	102,198	205,014
Cedar.....	2,116,721	1,955,577	11,000	150,144
Beech.....	648,774	613,016	15,780	19,978
Maple.....	578,373	547,471	12,582	18,320
Birch.....	267,661	261,080	6,581	850
Gum.....	208,550	207,700	850	850
Eastern tamarack.....	111,833	56,192	45,453	10,188
Hemlock.....	27,670	17,497	6,789	3,384
Cypress.....	19,751	14,763	.....	4,988
Western yellow pine.....	3,364	.....	.....	3,364
Douglas fir.....	2,491	.....	2,491	.....
All other.....	457,782	441,153	7,875	8,754

TABLE 7.—*Number of crossties reported purchased in 1915 by steam railroads representing 72.13 per cent of the mileage in the southern region, by classes of railroads and kinds of wood.*

Kind of wood.	Total.	Class I.— Operating revenues, over \$1,000,000.	Class II.— Operating revenues, \$100,000— \$1,000,000.	Class III.— Operating revenues, under \$100,000.
All kinds.....	17,840,648	15,571,927	1,250,774	1,017,947
White oak.....	9,596,488	8,720,461	413,889	462,138
Southern pine.....	4,612,224	3,624,229	678,685	309,310
Cypress.....	1,888,103	1,616,117	107,930	164,056
Red oak.....	512,054	468,538	25,919	17,597
Beech.....	372,320	370,716	104	1,500
Maple.....	372,313	370,715	.....	1,598
Chestnut.....	61,106	29,001	15,524	16,581
Western yellow pine.....	34,800	.....	.....	34,800
Gum.....	1,175	.....	200	975
Hemlock.....	432	.....	.....	432
Cedar.....	27	.....	27	.....
All other.....	389,606	372,150	8,496	8,960

PRESERVATION.

The deterioration of crossties in the United States by preventable decay uses up a great deal of timber. By adopting methods of preventing decay and using devices which retard wear, the quantity of wood consumed annually for this purpose could be greatly decreased.

There are many different causes of deterioration which necessitate the renewal of ties, the principal ones being decay, mechanical wear, breakage, insect attack, splitting, etc. In recent years the railroads have been prolonging the life of their ties by the use of preservatives, principally zinc chloride and creosote oils. By these means a number of species have been made available for ties which heretofore were

unfitted for this purpose because they did not have the proper decay-resisting qualities or immunity from insect attacks. Such treatment is often economical even with the woods that are more or less durable, the added life in service more than paying for the increase in the first cost.

Most of the crossties treated by the steam railroads in the United States are treated in closed cylinders permitting the application of a high pressure and designed to secure a heavy absorption of the preservative.

The schedules furnished to the steam and electric railroads did not request information as to the number of ties treated in 1915, but the Forest Service gathered statistics for this year from all of the treating plants in the United States. Table 8 shows the number of ties treated by the preserving plants during 1915, by kinds of preservatives and kinds of wood.

TABLE 8.—*Number of crossties treated by preserving plants during 1915, by kinds of preservatives and kinds of wood.*

Kind of wood.	Total.	Zinc chloride.	Creosote.	Zinc chloride and creosote.	Miscellaneous.
All kinds	37,085,585	17,819,284	17,077,069	2,182,712	6,520
Oak	16,885,517	7,954,492	7,365,673	1,565,352	.....
Southern pine	8,541,203	3,257,565	5,243,516	40,122	.....
Douglas fir	3,553,854	2,760,952	787,247	.....	5,655
Beech	2,933,737	100,000	2,469,202	364,535	.....
Western pine ¹	2,007,609	1,702,167	301,581	3,861	.....
Tamarack ²	932,038	449,660	390,017	91,496	865
Gum	277,886	204,653	1,650	71,583	.....
Birch	173,971	55	173,916	.....	.....
Elm	50,846	50,846	.....	.....	.....
Maple	36,942	316	36,626	.....	.....
All other	1,691,982	1,338,578	307,641	45,763	.....

¹ Includes lodgepole pine and western yellow pine.

² Includes western larch.

Since railroads often purchase large quantities of ties in one calendar year which do not receive preservative treatment until one or more years following, it is impossible to harmonize the data showing purchases with those showing preservative treatment. Furthermore, some treated ties reported in Table 8 may have been purchased by those roads which failed to report.

The treating plants reported a total of 37,085,585 crossties treated in 1915, which is about 38 per cent of the total number of ties reported purchased during that year. Of the total number of ties treated in 1915, 25,831,204 were hewed ties and 11,254,381 were sawed ties.

Oak ties were treated in larger numbers than any other species, contributing about 45 per cent of the total number treated. Southern pine was second in importance, constituting about 23 per cent of the total treated. Other species reported treated were Douglas fir, beech, western pine, tamarack, gum, birch, elm, and maple. There

were also treated a few miscellaneous ties, chiefly cypress, ash, sycamore, locust, and hickory.

Zinc chloride was the principal preservative used. Large quantities of creosote were also consumed in the treatment of ties. Zinc chloride and creosote in combination treated 2,182,712 ties, of which over 50 per cent were oak. The miscellaneous preservatives were used principally for Douglas fir and tamarack.

In treating ties with zinc chloride the average injection of the preservative was 0.5 pound per cubic foot, while with creosote oil the average quantity used was 8.5 pounds per cubic foot.

The practice of treating wood has increased because of the economic necessity of less frequent renewals of timber subject to decay. Prior to 1900 the wood-preserving industry developed slowly, and only during the last 10 or 15 years has it gained a permanent foothold in the United States. From a total of 12 plants in 1900 the industry has grown until at the present time there are 128 plants in commercial operation. Of this number 95 are pressure plants, 27 are nonpressure plants, and 6 are equipped for both pressure and nonpressure treatment. The industry in this country has been built up largely on crossties and other railroad material. Of the total quantity of 141,858,963 cubic feet of material of all kinds treated with preservatives in 1915, a little more than 78 per cent was crossties.

The number of ties treated each year, beginning with 1909, is shown in Table 9, together with the quantity of ties reported purchased.

TABLE NO. 9.—*Number of crossties reported purchased and treated, by years.*

Year.	Reported purchased.	Reported treated.
1909	123,751,000	20,693,013
1910	148,231,000	26,155,677
1911	135,053,000	28,394,140
1912	(1)	32,394,336
1913	(1)	40,260,416
1914	(1)	43,846,987
1915	97,106,651	37,085,585

¹ Statistics for these years not obtained.

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BULLETIN No. 550

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

August 9, 1917

CONTROL OF THE GRAPE-BERRY MOTH IN THE ERIE-CHAUTAUQUA GRAPE BELT.

By DWIGHT ISELY, *Scientific Assistant, Deciduous Fruit Insect Investigations.*

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INTRODUCTION.

Of the grape pests of the Erie-Chautauqua grape belt none is more baffling to control or more discouraging to the vineyardist than the grape-berry moth (*Polychrosis viteana* Clem.) (Pl. I). Owing to its direct attack upon the fruit, its ravages are felt at once wherever it is present in destructive numbers. It is very erratic in its occurrence, both locally and seasonally. In some years it may be practically absent from the majority of the vineyards of the belt, whereas in other years it is often not only the pest of first importance, but its ravages exceed those of all other pests combined.

To establish means of control for this pest experiments were conducted at North East, Pa., during the seasons of 1914, 1915, and 1916.¹

¹ This investigation was conducted under the direction of Dr. A. L. Quaintance, Entomologist in Charge of Deciduous Fruit Insect Investigations of the Bureau of Entomology. At the outset the work was greatly facilitated by the temporary association of Mr. Fred Johnson, formerly of this bureau, who placed at the writer's service his extended knowledge of grape insects and conditions in the Erie-Chautauqua grape region. The writer was assisted during the seasons of 1914 and 1915 by Mr. E. R. Selkregg and in 1916 by Mr. James K. Primm. Parallel with the experiments for direct control of the grape-berry moth, a study of its parasites was made by Mr. R. A. Cushman, from whom valuable cooperation was received. To these gentlemen and the cooperating vineyardists the writer wishes to express his appreciation for numerous courtesies.

NOTE.—This bulletin will be of interest to grape raisers in New York, Pennsylvania, Michigan, and Ohio.

The results of these experiments constitute the chief subject matter of this bulletin. Only such biological data as are necessary as a basis for the remedial work are included. Various control measures which have been employed are given place in the earlier part of the paper, but chief attention is devoted to spraying, which has proved to be the most effective means of control.

FOOD PLANT.

The grape, as far as is known, is the only food plant of the larva of the grape-berry moth, and since the larvæ usually feed upon the grape berry, it is from this habit that its common name is derived. Before the berries are developed, the few early larvæ feed in the blossom clusters. In confinement larvæ may feed sparingly on grape leaves and stems.

DISTRIBUTION.

The distribution of the grape-berry moth extends throughout the United States from east of the Great Plains to the Atlantic, and from the southern portion of the Canadian Province of Ontario to the Gulf of Mexico. The States from which it has been recorded in publications and in unpublished files of the Bureau of Entomology are as follows: Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Ohio, Indiana, Illinois, Wisconsin, Michigan, Missouri, Iowa, Nebraska, Kansas, Virginia, South Carolina, Florida, Alabama, Kentucky, Louisiana, Arkansas, and Texas. Most frequent complaints of its destructiveness have come to the Bureau of Entomology from New York, Pennsylvania, New Jersey, and Ohio.

ECONOMIC STATUS.

The grape-berry moth is a major grape pest in the eastern United States, on the whole probably being exceeded in destructiveness by the grape rootworm (*Fidia viticida* Walsh) and the grape leafhopper (*Typhlocyba comes* Say). However, its exact status as a pest is uncertain. In some grape-growing regions, within the limits of distribution, its presence is ignored or even unknown to the growers. It is exceedingly erratic and local in occurrence, and the damage which it inflicts varies greatly from year to year. The history of the grape-berry moth in the Erie-Chautauqua grape belt is an example of this variation. In the western part of the grape belt, in Pennsylvania, during the season of 1916 this insect was by far the most destructive grape pest; in the eastern part of the grape belt, in New York, it was not generally regarded seriously, yet Slingerland in 1904 reported it as very destructive throughout all of this region, particularly near Brocton, N. Y., where in one vineyard as high as 90 per cent of the fruit was ruined.

The extensive grape regions of Michigan have been the source of very few complaints of loss due to the grape-berry moth. In the summer of 1915 the writer visited many vineyards in the vicinity of Benton Harbor, St. Joseph, Paw Paw, and Lawton, Mich., and found the berry moth present in practically all of them, although usually in small numbers. Its destructiveness in this region is obscured by the greater and more consistent injury by the black-rot fungus, and probably injury by the grape-berry moth is often attributed to the black-rot fungus. In contrast to this, in the Ohio grape regions it has been consistently destructive and the leading grape pest for years. Even in a region where the grape-berry moth is a recognized pest it is by no means consistent in occurrence, and may be erratic and local even within a vineyard. In the vicinity of North East, Pa., in the western part of the Erie-Chautauqua grape belt, in most seasons fully half of the vineyards are practically free from it. In others the outside rows, ends of rows, or irregular spots are heavily infested, while the rest is practically free. Yet there are many vineyards that annually sustain the loss of from one-fourth to one-half the crop.

DESTRUCTIVENESS WITHIN A VINEYARD.

The destructiveness of the grape-berry moth is underestimated greatly even in vineyards where it is recognized as the chief pest, and where the infestation is light it is usually ignored. This is due to the fact that "wormy" grapes, unless very heavily infested, will bring a price comparatively near the standard price, seldom with a reduction of more than 10 per cent. Even when the infestation approaches total, the price may be much nearer to the standard for grapes than the price for cider apples is to the standard price for apples. Because of this the vineyardist is apt to consider the reduction in price as the chief loss and largely disregard what may be a greater charge against the berry moth—the reduction in weight.

The berries infested by first-brood larvæ (see Pl. II, fig. 1) are totally lost, although if they are destroyed very early in the season this loss may be partially offset by increased weight in the rest of the cluster. Those infested by the second brood (see Pl. II, fig. 2), which the larvæ have left or in which the larvæ are well grown, lose weight rapidly; by the end of the season they are little more than dry shells and have but a fraction of their former weight (Pl. III, fig. 1). This loss varies greatly, depending upon the time when the berries are infested and upon the time of harvest.

"Wormy" grapes are of course largely excluded from the market for basket grapes, for unfermented juice, and for some wines, unless all of the "wormy" berries are trimmed out. This exclusion from certain markets may in certain years represent a considerable loss.

If the infested berries are trimmed out of the clusters the loss of their weight is total in addition to the cost of trimming.

While the berry moth is not as generally destructive as the grape rootworm or grape leafhopper, it is capable of inflicting greater losses than either to a single season's crop, and neither of these pests will appear in destructive numbers with such alarming rapidity in a vineyard which has been apparently free from them as will the grape-berry moth. When it is present at all in a vineyard it always causes a loss in weight and is a constant menace to the grape industry in that vicinity.

SUMMARY OF SEASONAL HISTORY AND HABITS.¹

Before considering control measures, a summary of the seasonal history and habits upon which these measures are based will be given.

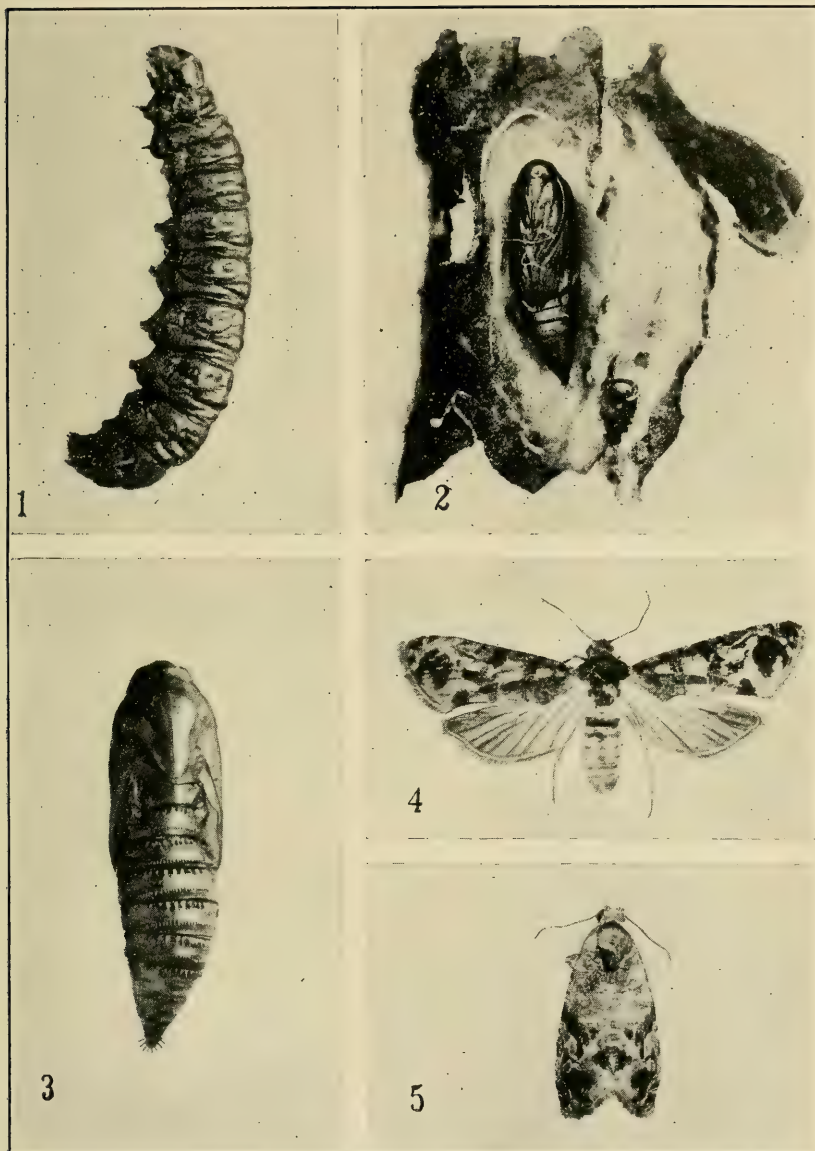
There are two broods of the grape-berry moth that must receive economic consideration. The first brood, resulting from the hibernating generation, is comparatively small, owing to high winter mortality of the pupæ. The earliest recorded emergence of moths is May 29 and the latest July 26; however, the bulk of the emergence begins between the 10th and the 25th of June, varying with the season, and usually is ended within 3 weeks. Within 4 to 6 days after emergence the moths (Pl. I, figs. 4, 5) begin depositing eggs, preferably on grape berries. Incubation requires about 6 days. Thus the hatching period of large numbers of larvæ begins from June 20 to July 5, depending upon the season, and continues for about 3 weeks.

The beginning of this period is almost coincident with the falling of the grape blossoms and the setting of the fruit. The larval feeding period averages 23 days, after which the larvæ (Pl. I, fig. 1) spin cocoons in leaves on the vine, and in an average of 13 days emerge as moths. Some pupæ (Pl. I, fig. 3), however, do not transform at this time but remain in the cocoon (Pl. I, fig. 2) until the following spring.

The earliest recorded emergence of summer-brood moths is July 12 and the latest is after the middle of September. A heavy emergence of moths begins in a normal season in the latter part of July, and in backward seasons may continue as late as the earlier part of September. Although the second brood is only a partial one, it is by far the more numerous and destructive. It may escape serious attention from the vineyardists until shortly before harvest, when the well-grown larvæ begin to leave the berries they first attacked and to enter others.

The development of this brood is slower than that of the first. In a normal season the larvæ are cocooning in large numbers by the latter part of September and by the middle of October most of them

¹ This summary is based on the life-history studies of the grape-berry moth by Johnson and Hammar, and studies by the writer and his associates, the details of which have not yet been published.



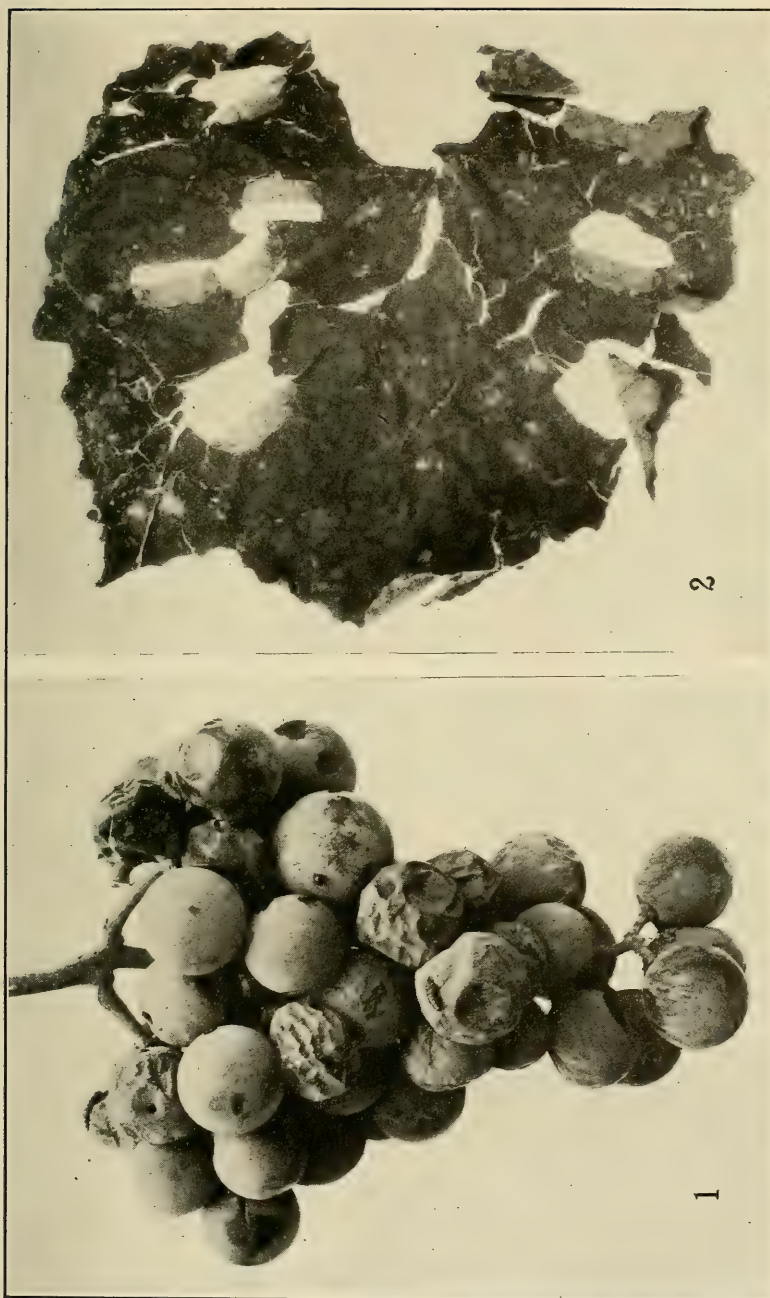
THE GRAPE-BERRY MOTH (*POLYCHROSIS VITEANA*).

FIG. 1.—Larva. FIG. 2.—Pupa (ventral aspect) in cocoon. FIG. 3.—Pupa (dorsal aspect). FIGS. 4, 5.—Adult. All greatly enlarged. (Original.)



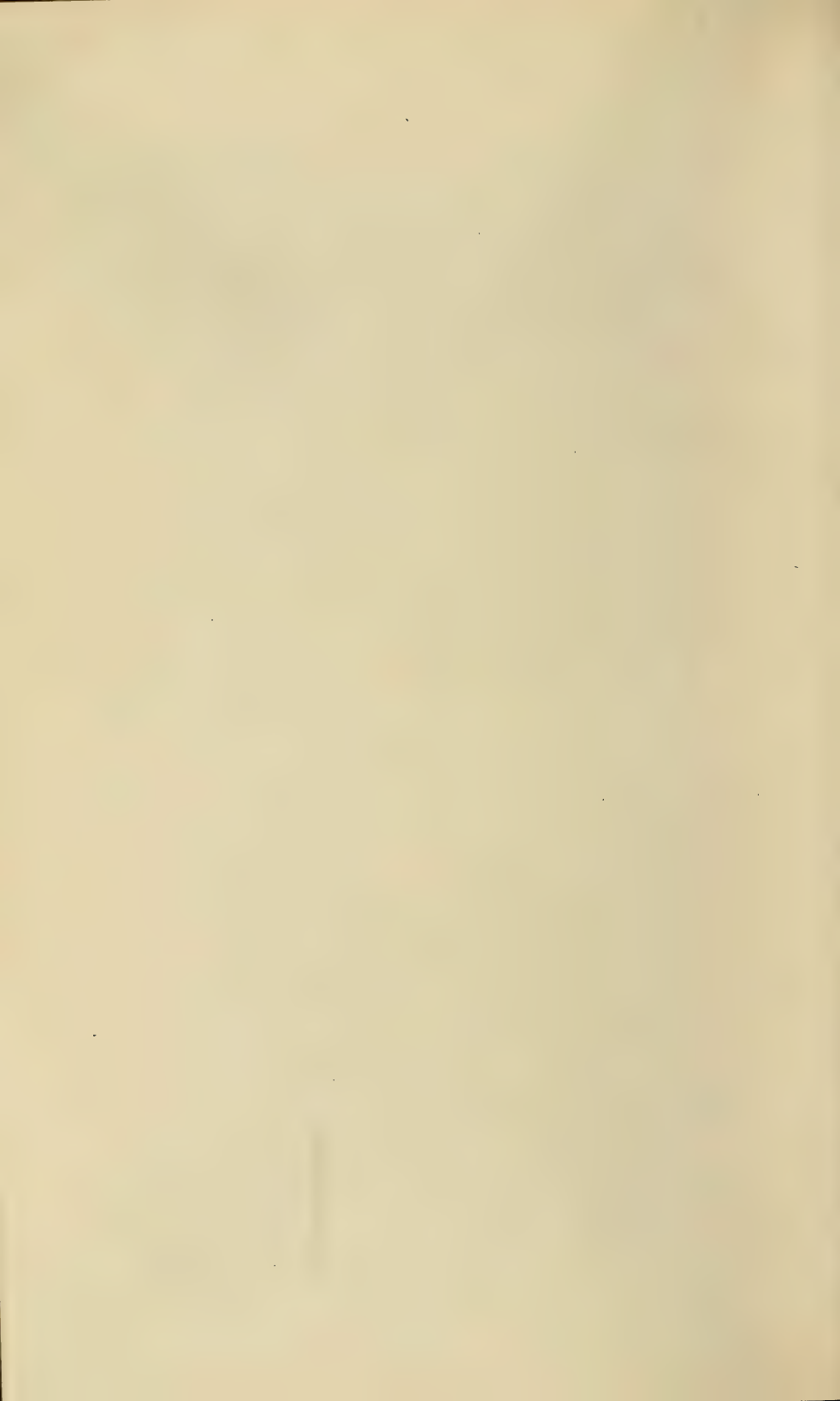
GRAPE CLUSTERS ATTACKED BY FIRST-BROOD GRAPE-BERRY MOTH LARVÆ.

FIG. 1.—Injury by earliest larvæ, showing webbing of cluster. FIG. 2.—Injury by later larvæ, showing undersized, cracked, and shriveled berries which have begun to fall. Note second-brood eggs on surface of berries. (Original.)



DAMAGE BY THE GRAPE-BERRY MOTH.

FIG. 1.—Grape cluster at harvest time, heavily infested with second-brood grape-berry moth larvae. FIG. 2.—Cocoons in sodden grape leaf under trellis.
(Original.)



have left the berries. However, in the very late autumn of 1915 the majority of the larvæ did not leave the berries until after October 25.

Winter is passed in a cocoon, usually spun in a decayed grape leaf under the trellis. (Pl. III, fig. 2.)

FEEDING HABITS OF LARVÆ.

The very few early larvæ which hatch before the grape blossoms fall feed in the blossom cluster. But most of them, coming after the grapes are set, eat at once into the berry, causing the characteristic purple spotting and cracking of grape berries.

The point of entrance may be anywhere on the surface of the grape berry, but before the berries touch, about half of the larvæ enter around the stem attachment. Of 500 infested berries counted on July 14, 1916, about 12 days after setting of grapes, 266 were entered at the stem end and the other 234 from other parts of the grape berry. After the grape berries reach the stage of growth where they begin touching, the point of contact becomes the most common place of entrance.

The early larvæ, which hatch when the grape berries are still small, destroy many more berries than do larvæ which hatch after the grapes are larger.

FLIGHT OF MOTHS.

The distance which moths of this species may fly in large numbers is uncertain, but as a rule the spread of infestation is slow. In one instance serious infestation advanced from a heavily infested vineyard into an adjacent young vineyard not more than 100 or 120 feet distant. In this vineyard there could have been no previous infestation, as it had just come into bearing. Some infested berries were found 350 feet from the older vineyard, but very few. On the other hand, the following season a vineyard about 1,100 feet wide, newly in bearing, was traversed and infested heavily by a single generation. The spreading of infestation probably is much influenced by weather conditions at the time of the flight of moths. While it may be slow ordinarily, no vineyard is immune from rapid infestation in a vicinity where the berry moth is present.

HISTORY OF CONTROL METHODS.

Measures to control the grape-berry moth, since its appearance as an economic pest, have developed gradually from many sources. The first considerable advance toward a solution of the problem, however, was made by the biological and systematic studies of Slingerland (9)¹ and Kearfott (8) in which they definitely determined the limits of the species and the fact that the grape was its only food plant; and by Slingerland's field experiments, which

¹ Reference is made by number to "Literature cited," p. 42.

were the first in which spraying was attempted as a primary means of reducing its destructiveness.

Gathering and burning grape leaves in the fall, to destroy the hibernating insects, was recommended first by Walsh and Riley (1). This recommendation remained in good standing until it was questioned by Webster (5), because he was unable to rear any moths from collected leaves, and since that time it has appeared less frequently. Slingerland recognized the general futility of this practice and termed it "the least effective measure."

The bagging of clusters to prevent infestation was first recommended by Lintner (2).

Picking and destroying infested fruit was recommended by Bogue (6) in a general way. Slingerland (9) recommended the picking of grape berries infested by first-brood larvæ and also advised the destruction of the "trimmings."

Burying the hibernating pupæ by plowing was also first suggested by Slingerland (9).

Marlatt (3) first recommended spraying, but did so doubtfully, for at that time the berry moth was regarded as a general feeder. Following this both Beach (4) and Bogue (6) disparaged spraying as "of little value." Webster (5), however, observed that the pest could be controlled by spraying, and Felt (7) reported, as an incidental to rootworm control, that spraying had reduced the berry-moth infestation 50 per cent.

Slingerland's work, mentioned above, was followed by a number of important contributions. Gossard and Houser (11), in Ohio, recommended the addition of soap to an arsenical spray and the use of "trailers" in applying it. A thorough life-history study, the first upon which a satisfactory spray schedule could be based, was made by Johnson and Hammar (16) and a combination of control measures was recommended. Goodwin (19), in Ohio, recorded satisfactory results by spraying, using 3 pounds of arsenate of lead (powdered) to 50 gallons of liquid, an adhesive, and an application with "trailers." His spray schedule differed from the preceding by being directed largely against the second-brood larvæ.

CONTROL EXPERIMENTS AT NORTH EAST, PA.

Experiments to establish a control for the grape-berry moth, conducted at North East, Pa., were carried on in vineyards on a commercial scale whenever possible. Vineyards chosen for experimental work were those which had been infested heavily the previous season and as far as possible those in which the infestation had been distributed rather evenly.

To determine the degree of success of the different methods tried in vineyards, whenever it was feasible, counts were made of the sound

and infested berries in the different experimental plats and in the adjacent untreated check plats. Counts of infested berries in each of the different plats were made the first season from four 40-pound crates of harvested fruit. In all plats in a single vineyard, the crates were taken from the same relative positions. During the following seasons a count was made from all of the fruit from 12 to 25 vines. These vines were taken at intervals throughout the length of each plat so as to include all conditions, and in the same relative positions in all plats in the same vineyard.

ELIMINATING VINEYARD CONDITIONS FAVORABLE TO THE GRAPE-BERRY MOTH.

WINTER EXPOSURE.

Protected situations in vineyards, along hedgerows, fences, or woodlots, and low-lying spots, are invariably more heavily infested by the berry moth than are the less protected portions of the same vineyard. On the other hand, exposed knolls seldom are infested heavily. This variability in infestation, according to Johnson and Hammar, is due to protection afforded to hibernating insects and the consequent reduction of winter mortality. Goodwin attributed the heavier infestation in low-lying spots to washing of cocoons in winter. Observations by the writer confirmed both these conclusions and also indicated that wind at the time of flight of moths is a factor, as moths drift with the wind into these low-lying spots.

Of these factors causing heavy infestation, one at least, winter protection in a vineyard, can be regulated more or less by artificial means. The importance of this factor was tested during the winter of 1915-16.

Different lots of cocoons, collected in the fall of 1915, were placed in cylindrical baskets of 20-inch wire mesh and wintered in vineyards in protected and in exposed situations, and also in the insectary yard under a covering of leaves held in place by wire screen. To forestall accidents each lot was divided into two baskets. In May, 1916, the cocoons were removed and placed in rearing jars. Table 1 shows the effect of the different conditions upon mortality:

TABLE 1.—*Percentage of emergence of the grape-berry moth hibernating in exposed and in protected situations.*

Lot No.	Situation.	Number of cocoons.	Number of moths emerged.	Emergence.
I.	In vineyard, naturally exposed; crest of windswept knoll....	350	20	<i>Per cent.</i> 5.71
II.	In vineyard, naturally protected by brush and drifted snow....	350	86	24.05
III.	In vineyard, artificially protected by covering with 2 inches of earth.....	150	45	30.00
IV.	In insectary yard, artificially protected under "leaf blanket".	350	154	44.00

The rearing records show clearly the value of winter exposure in a vineyard in reducing the number of moths that will be present the following season.

A comparison of Lot III with Lot I shows how plowing, if injudiciously practiced, may increase vineyard infestation. If a furrow is thrown up to the vines in late fall, after the larvæ have spun their cocoons under the vines, it will give the hibernating pupæ winter protection. And if the earth is plowed away before the time of moth emergence, these artificially protected insects are released.

It is obvious that the protection of hibernating pupæ should be avoided whenever practicable. Plowing to the vines in late fall after harvest should be avoided as far as possible. Hedge rows and brush along vineyards should be removed. This last coincides with good vineyard practice and is of value also in reducing danger of leaf-hopper injury.

UNNECESSARY SHADE.

Shade in a vineyard favors the berry moth. Where the growth is vigorous and the foliage dense, or where vines have been trained so as to give an unusual amount of shade, the infestation invariably is heavier than in adjacent parts of the vineyard or in vines giving less shade. Vigorous growth is desired, of course, but when horticultural considerations do not prevent, vine training systems which give unusual shade should be avoided.

DESTRUCTION OF LEAVES IN FALL.

Destruction of the hibernating generation in the cocoon, the first control measure to be recommended, was tried in the fall of 1914. In a small block in the McDonald vineyard the writer attempted removing cocoons by raking out the leaves under the trellis. Upon examination of the leaves thus collected it was found that practically all of the cocoons had fallen out. In the following season when counts of berries infested by first-brood larvæ were made no difference between this block and the check was noted.

During the seasons of 1914, 1915, and 1916 the writer and his associates collected approximately 30,000 cocoons for rearing. No system could be devised to aid in collecting these cocoons and the work was necessarily done by hand. It was always a slow and tedious process and is impracticable as a means of control, since the cocoons are usually spun, except in very dry seasons, in leaves that are sodden and ready to fall apart, and not in fresh, crisp leaves. Frequently the cocoons are spun in the leafage of chickweed and sorrel and in other leaves which ordinarily would escape collection.

BAGGING GRAPE CLUSTERS.

The bagging of grapes immediately after the setting of fruit, to prevent infestation by the berry moth, was tried in the season of 1914 in the vineyard of the late Mr. J. L. Spofford. Clusters on 25 vines were covered with paper bags, 2 and 3 pound sizes. The bags were fastened on the clusters with long pins and a slit was cut in the bottom of each bag to drain out whatever water might collect.

The experiment was successful in so far as exclusion of the moth was concerned. Only 20 wormy berries were found in 100 clusters which averaged 32 berries to the cluster. This was a total infestation of only 0.62 per cent. However, the test was not severe, for the infestation of the grapes on the surrounding vines was light, being only 13.2 per cent. The infestation of the bagged clusters was due no doubt to oviposition which had taken place before the bags had been placed on the clusters.

The cost of bagging, however, is prohibitive in commercial vineyards in the Erie-Chautauqua grape region. Brooks (10) records, in control measures against the grape curculio, that one laborer in his employ could bag 1,200 clusters a day. This was probably exceptionally fast work. Using this as a basis and figuring 550 vines per acre, each bearing 40 clusters, or a total of 22,000 clusters, the minimum cost of bagging an acre of grapes, according to 1914 prices, would be as follows:

Applying bags.....	\$22.91
Cost of bags, \$1.15 per 1,000.....	25.30
Pins, \$0.10 per 1,000.....	2.20
Total.....	50.41

This method of control, if followed at all, would be practicable only in a garden vineyard.

HAND PICKING INFESTED BERRIES.

Attempts to control the grape-berry moth by hand picking the fruit infested by first-generation larvæ, in order to prevent subsequent infestation, were made in the seasons of 1914 and 1915. Clear-cut comparisons between the hand-picked plats and the checks were impossible because of the flight of moths from one row to another.

EXPERIMENT IN ADAMS AND GILL VINEYARD OF NORTH EAST, PA., 1914.

The plat chosen for the hand-picking experiment was a narrow strip of eight rows, containing slightly more than 1 acre, located in a corner of the vineyard, and bordered by a hedgerow. This plat was from three to four times as grossly infested as was the greater part of the vineyard. After the six rows nearest the hedge, the percentage of infestation declined quite rapidly as compared with that of the rest of the vineyard, and the south end, which was lower than the rest of the plat, was even more heavily infested than the rows next to the hedge.

Hand picking of wormy fruit was done July 7 and 8 and again between July 25 and August 1. The time of the first picking occurred about 10 days after the falling of the blossoms. The actual time expended in this work was 35.5 hours for the two men employed, or a total of 71 hours. The second picking, which was more or less interrupted by rain, developed that about 12 per cent of the berries were wormy.

The counts of wormy berries taken at harvest time showed the following percentages of infestation:

	South end. <i>Per cent.</i>	North end. <i>Per cent.</i>
Hand-picked plat.....	84.4	24.9
Check.....	68.2	25.3

This shows as a curious result that the hand-picked area was more heavily infested than the check, probably owing to the flight from the vineyard at large of moths which settled in this narrow protected area.

EXPERIMENT IN MOORHEAD VINEYARD, MOORHEADVILLE, PA., 1914.

A plat of 16 rows, 2 acres in area, was chosen in the middle of the vineyard of the late R. E. Moorhead. The infestation was comparatively uniform throughout. Hand picking of infested fruit was done three times, July 2 and 3, again from July 17 to 21, and again from August 10 to 15. The total time occupied in treating the 2 acres was 55 hours, or 27½ hours per acre.

Counts of infested berries from four crates of grapes from the hand-picked plat were made and the same from the check plat. The following shows the percentage of infestation:

Hand picked.....	14.7 per cent.
Check.....	27.4 per cent.

EXPERIMENT IN THE McDONALD VINEYARD, NORTH EAST, PA., 1915.

The heavily infested ends of 12 rows of a vineyard section adjoining a woodlot were chosen for this experiment. The picked area extended along the rows about 70 feet. The plat was picked over once, August 5 and 6, requiring a total of 22 hours' work for approximately one-fifth of an acre.

Counts taken just before harvest from representative vines in the hand-picked plat and in the check plat showed the following results:

TABLE 2.—Counts in hand-picking experiment, McDonald vineyard, North East, Pa., 1915.

Plat.	Number of vines.	Number of clusters.	Number of berries.	Infested berries.	Infested berries per 100 clusters.	Infestation.
						<i>Per cent.</i>
Hand picked.....	12	520	13,664	2,592	498.4	13.12
Check.....	12	546	16,513	6,162	1,136.6	34.93

EXPERIMENT IN THE MOORHEAD VINEYARD, MOORHEADVILLE, PA., 1915.

A plat of 22 rows, comprising nearly 3 acres, part of which had been hand picked in the experiment in 1914, was chosen for experimental work. No difference in infestation was shown in the two parts of this plat, probably because the effect of the work of the previous season had been obscured by the flight of moths from one part to another. However, the cumulative results probably were of considerable value, as the infestation in this section of the vineyard was much lighter than it had been the previous season, while the infestation of the vineyard as a whole was about the same.

The plat was hand picked only once for infested berries, between July 30 and August 5, the time required being lengthened by rain. The actual labor required was 43 hours.

Counts taken just before harvest on 12 representative vines in the hand-picked plat and in the check plat showed the following results:

TABLE 3.—*Counts in hand-picking experiment, Moorhead vineyard, North East, Pa., 1915.*

Plat.	Number of vines.	Number of clusters.	Number of berries.	Infested berries.	Infested berries per 100 clusters.	Infesta- tion.
Hand picked.....	12	408	11,793	945	242.3	<i>Per cent.</i> 8.01
Check.....	12	360	11,793	1,677	465.8	14.22

DISCUSSION.

An average, from the different experimental plats, of the time required to hand pick the "wormy" berries in an acre of grapes was 55.75 hours. At 12½ cents per hour the cost per acre would be \$6.97.

This method, hand picking wormy berries, was employed in a number of vineyards by the owners during the seasons of 1914 and 1915 and as a rule the beneficial results were not readily apparent. In several instances the value of the work was reduced by picking the berries after most of the "worms" had left the grapes, and in others by inefficient laborers who missed a large percentage of the "wormy" berries. In some cases the infestation probably was considerably reduced and in one instance apparently successful control resulted. In this vineyard the infestation was restricted to a narrow strip comprising a few rows which were hand picked by the owner himself about once a week.

From the experiments and observations of the two seasons, hand picking of "wormy" berries could be relied upon to reduce berry-moth infestation but not to control it. The difficulty of securing ample and efficient labor at a time when it is needed stands in the way of adopting hand picking as a general method of repression, and the ultimate cost is thus too high when only partial control may be

expected. It might be of use in a garden vineyard or in a commercial vineyard where only a small area is infested, but on the whole it can not be regarded as a satisfactory remedial measure.

EARLY HARVESTING.

Early harvesting of grapes and removal of the "trimmings" remove great numbers of berry-moth larvæ which otherwise would be left to overwinter in the vineyard. This practice is limited, for the grape harvest usually continues long after a majority of the berry-moth larvæ have cocooned. However, it should be applied to the worst infested areas in the vineyard.

The degree of reduction of hibernating pupæ by comparatively early harvesting is best shown by counting cocoons under vines. During the harvest of 1915, which was an extremely late season, one part of the edge of a vineyard, where the infestation was approximately 50 per cent, was picked October 12 to 15, and all grapes were removed; the other part was picked October 24 to 26. The count of cocoons under 14 vines from each block was as follows:

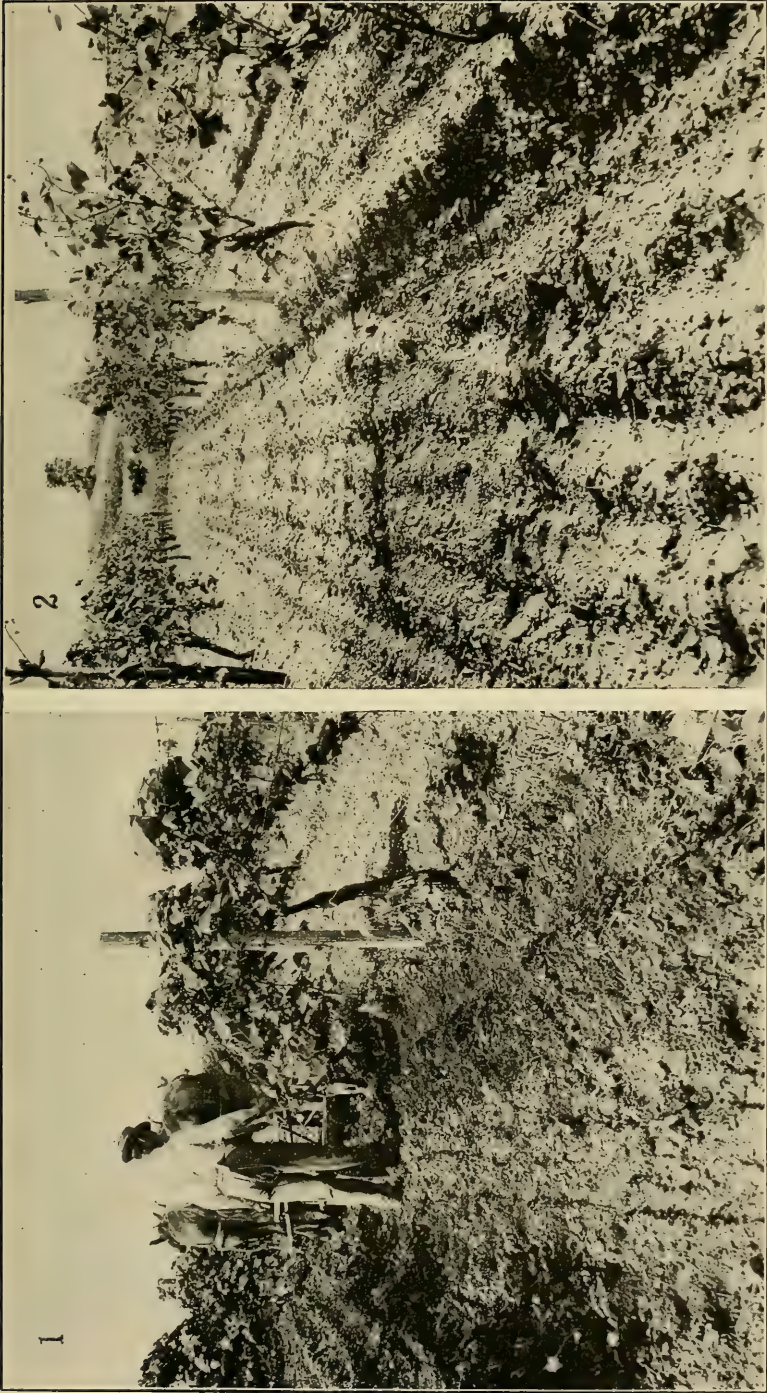
Date picked.	Number of vines.	Cocoons found under vines.	Cocoons per vine.
Oct. 12 to 15.....	14	92	6.59
Oct. 24 to 26.....	14	621	44.50

As stated, this was an exceptionally late season. During the season of 1916, according to the records, half the larvæ had left the grapes by October 4. Johnson and Hammar found that during normal seasons the majority of the berry-moth larvæ left the grapes by October 10.

Early harvesting is more valuable in avoiding loss of weight in the crop attacked than in reducing the following season's infestation. Grapes badly infested with the berry moth lose weight rapidly after the picking season begins, owing to the movement of larvæ from infested to sound berries, and to the subsequent shrinking of previously infested berries.

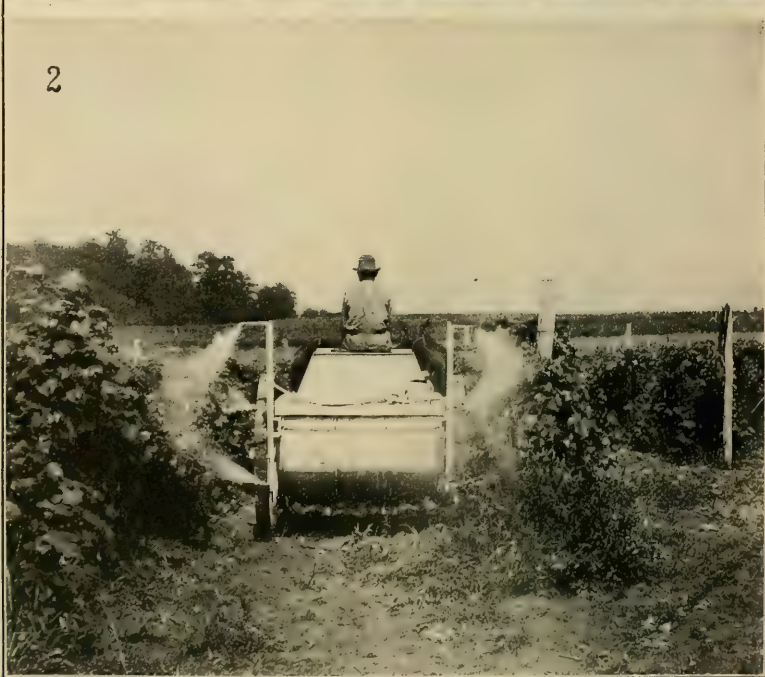
BURYING HIBERNATING PUPÆ.

"Plowing under" the hibernating generation previous to the time of moth emergence and keeping it covered during the earlier part of this period had been practiced for a number of years in the vicinity of North East, Pa., although no definite knowledge as to the effectiveness of the practice had yet been ascertained. (See Plate IV.) In late fall or early spring earth is thrown up by a plow to the vines on both sides covering the hibernating pupæ under several inches of earth. This earth is allowed to remain until after the general emergence of moths in the spring, when it is removed with a horse-hoe.



CULTURAL METHODS AGAINST THE GRAPE-BERRY MOTH.

FIG. 1.—Removing ridge of earth under trellis with horse hoe. FIG. 2.—Ridge of earth before horse hoeing. (Original.)



SPRAYING AGAINST THE GRAPE-BERRY MOTH.

FIG. 1.—“Trailer” method of applying spray. FIG. 2.—“Set nozzle” method of applying spray. (Original.)

The effect of this treatment is to prevent the moths from escaping through the covering of earth.

In a number of vineyards where this method of control has been practiced, check rows were maintained in which the earth was removed early in the season, in order to determine, if possible, the effects of the practice. No definite results were obtained. If small checks were left the flight of moths obscured the results altogether; and in larger checks variation of infestation interfered. In some vineyards the infestation appeared to be reduced greatly, but in none was it controlled.

The principle of this practice was proven correct, however, by a small experiment in the insectary yard during the season of 1916.

Three lots of 300 cocoons each, collected in the fall of 1915 and wintered in the insectary yard, were placed in 8-inch flowerpots. Two lots were covered with from $2\frac{1}{2}$ to 3 inches of earth; the third was left uncovered. The emergence record totals as follows:

From 600 cocoons buried under earth no moths emerged.

From 300 cocoons not buried 103 moths emerged.

In a number of small lots 60 cocoons were placed in glass vials where the action of the moths after emergence could be observed. These cocoons were covered with earth at depths varying from $\frac{1}{2}$ inch to 3 inches. Upon emergence none of the moths were able to work their way upward through the covering of earth. It should be remembered, however, that results as satisfactory as these can not be expected under field conditions.

"Horse hoeing" away from the vines, if done during the grape blossoming period, would also destroy grape-rootworm pupæ which are transforming at that time (13, 18).

SPRAYING.

Experiments with poison sprays were conducted during each of the three seasons. All of the vineyards but one were planted to Concord grapes, which is the standard variety for this grape-producing region. In 1916 experiments were conducted also in a single vineyard of Niagara grapes.

Weather conditions affecting spraying operations and results differed strikingly during the three seasons. Records from the Weather Bureau station at Erie, Pa., on Lake Erie, 16 miles west of North East, showed that in 1914 the months of July and August were nearly normal. The next year was colder with excessive rains during these two months, while the corresponding period of 1916 was very warm and dry. The average mean temperature for these two months in 1915 was 2.4° below normal and the rainfall was 7.95 inches above normal. In 1916 the average mean temperature was 3.7° above normal and the rainfall was 3.39 inches below normal.

In rainfall during these two months the two seasons showed a difference of 11.34 inches.

METHODS OF APPLICATION.

All spray applications were made with a gasoline-power sprayer. Two methods of applying the spray were used. (See Pl. V.) By the one, spray was applied to the vines by a "set-nozzle" arrangement at the rear end of the machine. From vertical pipes on each side of the machine two short spurs were directed outward, each bearing an angle nozzle which drove the spray outward and upward and as far as possible under the leaves. The lower spur was below the lowest wire of the trellis. The height of this spur could be varied somewhat to suit the trellis. A third and upper nozzle was mounted on a longer spur and projected over the trellis, the nozzle being directed downward. The "set-nozzle" method of application of spray is more generally used against the grape rootworm and mildew, because it is least expensive from the labor standpoint.

By the other method single nozzles were mounted on short rods attached to the machine by trailing hose, and the spray was directed to the grape clusters by hand. This "trailer" method has been recommended by Johnson in his investigations against the grapevine leaf-hopper.

The two methods require about the same amount of spray material per acre. When "set nozzles" were used about 150 gallons of spray was applied per acre; with "trailers," about 125 gallons per acre was used immediately after the falling of the blossoms, and about 175 gallons when the berries began to touch.

When applications were made with "set nozzles" the machine was driven along every row, but when "trailers" were used the machine was usually driven only along alternate rows, the rodman on each side being able to reach through the trellis and spray both sides of the row.

The spraying schedules followed in these investigations were based largely on the seasonal-history studies on the grape-berry moth made by Johnson and Hammar, modifications being made the second and third seasons.

SPRAYING EXPERIMENTS IN 1914.

From a control standpoint the spraying in 1914 was a failure, although it did bring about a consistent reduction in the numbers of the berry moths. Furthermore, results in the Phillips vineyard were of uncertain value because of the wide variation of infestation as shown by the checks. The negative results were of value, however, since they indicated the necessity of a radical revision of spraying practice.

In applying the spray, the difficulty in covering the grape clusters with "set nozzles" was apparent. It was noted also that even when

the spray was applied directly to the grape clusters with "trailers" it did not adhere to the waxy skin of the grape berries, except when the solution to which soap had been added was used. These features, (1) the application of the spray directly to the grape clusters and (2) the addition of soap to the solution, were the most important changes which were suggested by this season's work.

EXPERIMENT IN THE MOORHEAD VINEYARD,
MOORHEADVILLE, PA., 1914.

Experimental work in the Moorhead vineyard was conducted in a section of 38 rows, comprising about 5 acres, which was divided into 4 plats of 8 rows each and one of 6 rows, the latter used as the check plat. The arrangement of the plats is shown in the diagram (fig. 1). The vineyard was rather evenly infested throughout.

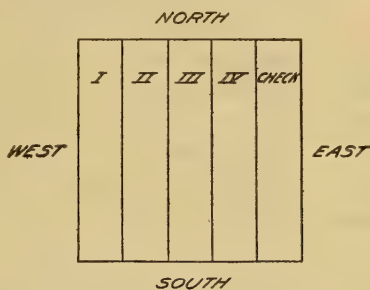


FIG. 1.—Diagram showing arrangement of experimental plats in Mr. J. M. Moorhead's vineyard, Moorheadville, Pa., 1914. (Original.)

TABLE 4.—*Spray mixtures used, methods and dates of application, and percentages of infestation in experimental plats, Moorhead vineyard, Moorheadville, Pa., 1914.*

Plat No.	Dates sprayed with set nozzles.	Dates sprayed with trailers.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Water.	Infestation.
				Lime.	Copper sulphate.			
I.....	June 9, 23, and July 9.....		Pounds. 3	Pounds. 3	Pounds. 3	Pounds. 50	Gallons. 25.6	
II.....	June 23 and July 9.....		3	3	3	50	26.7	
III.....	June 23.....	July 9	3	3	3	50	27.8	
IV.....	do.....	July 10	3	3	3	50	22.9	
Check, unsprayed.							31.8	

¹ Last application only.

Though the experiments in this vineyard showed a consistent reduction of infestation, definite control of the grape-berry moth was not established. In one plat the results appeared somewhat more favorable than in the others and offered a suggestion for further investigation. Soap was added to the spray mixture and "trailers" were used in applying it, but as these changes had been made only for the last application they could not affect the results materially.

EXPERIMENT IN THE PHILLIPS VINEYARD, NORTH EAST, PA., 1914.

Experimental work in the Phillips vineyard was conducted in a section which included 44 rows, covering about 7 acres. It was divided into 7 plats of 6 rows each. The middle row of each plat and the two rows at one side were chosen for checks. The arrangement of the plats is shown in the diagram (fig. 2).

TABLE 5.—*Spray mixtures used, methods and dates of application, and percentages of infestation in experimental plats, Phillips vineyard, North East, Pa., 1914.*

Plat No.	Dates sprayed with set nozzles.	Dates sprayed with trailers.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Nicotine sulphate.	Water.	Infestation.
				Lime.	Copper sulphate.				
I.....	June 12, 26, and July 12.....	.....	Lbs. 3	Pounds. 3	Pounds. 3	Pounds.	Pints.	Galls. 50	Per ct. 5.2
II.....	June 26 and July 12.....	.....	3	3	3	.....	.....	50	4.5
III.....	June 26.....	July 12	3	3	3	.....	.....	50	7.2
Check A.	.....	.....	.....	.....	.....	.....	.....	.....	8.7
IV.....	June 26 and July 12.....	.....	3	3	3	1 1	.....	50	9.5
V.....	June 26.....	July 12	3	3	3	1 1	1 1	50	5.5
VI.....	June 26.....	July 12	3	3	3	1 1	.....	50	17.9
Check B.	.....	.....	.....	.....	.....	.....	.....	.....	52.4

¹ Last application only.

The infestation in this vineyard had been very heavy the previous season, but in 1914 it was light. Check plat B was much more heavily

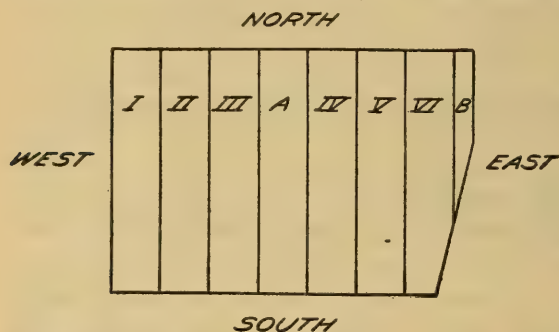


FIG. 2.—Diagram showing arrangement of experimental plats in Mr. M. D. Phillip's vineyard, North East, Pa., 1914. Sprayed plats are marked with Roman numerals, check plats with letters. (Original.)

infested than the adjacent sprayed plat; whereas this plat was much more heavily infested than check plat A. While it is probable that spraying did reduce the infestation somewhat in this plat and in the one next to it, because of the wide variation of infestation in the unsprayed

checks, this can not be stated definitely. The similarity of results in check plat A and the sprayed plats adjoining it indicates failure in control.

SPRAYING EXPERIMENTS IN 1915.

The season of 1915 was marked by extremely heavy rainfall during the spraying season and during the month following. Spraying operations were interrupted frequently or delayed by rain and as a result spraying as a remedial measure was put to a very severe test. However, when the final counts were made, all plats sprayed with solutions containing arsenate of lead and soap and applied with "trailers" showed a satisfactory reduction of infestation from a commercial standpoint. The contrast in infestation between the sprayed plats and others was commented on with astonishment at harvest time by pickers who were ignorant that any remedial measures had

been employed. Tables 6 and 7 will give in detail the treatments applied in the different vineyards and the results as shown by percentages of "wormy" fruit.

EXPERIMENT IN THE BARTLETT VINEYARD, NORTH EAST, PA., 1915.

Experimental work in this vineyard was conducted in a square corner section of about 2 acres which had been very heavily infested in 1914. It was divided into two large plats of 11 rows each with an 8-row check between and 2 narrow plats of 3 rows each outside of the larger ones.

The adjacent vineyard also was unsprayed and used as a check. The arrangement of plats is shown in the diagram (fig. 3).

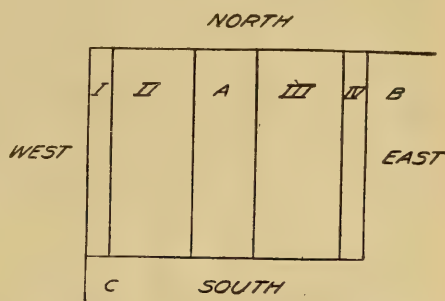


FIG. 3.—Diagram showing arrangement of experimental plats in the vineyard of Mr. A. P. Bartlett, North East, Pa., 1915. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

TABLE 6.—*Spray mixtures used and method and dates of application in experimental plats, Bartlett vineyard, North East, Pa., 1915.*

Plat No.	Dates of spraying.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Nicotine sulphate. ¹	Water.	Method of application.	Remarks.
			Lime.	Copper sulphate.					
		Pounds.	Pounds.	Pounds.	Pounds.	Pints.	Gallons.		
I.....	July 6, 19	3	3	3	1	$\frac{1}{2}$	50	Trailers.	Double sprayed. ²
II.....	do.....	3	3	3	1	$\frac{1}{2}$	50	do.....	Single sprayed. ²
III.....	do.....	5	3	3	1	$\frac{1}{2}$	50	do.....	Single sprayed. ²
IV.....	do.....	5	3	3	1	$\frac{1}{2}$	50	do.....	Double sprayed. ²

¹ Last application only.

² Plats marked "double sprayed" were sprayed twice on each date of treatment, the second spray being applied as soon as the first had dried.

TABLE 7.—*Percentage of infestation in experimental plats, Bartlett vineyard, North East, Pa., 1915.*

Plat No.	First brood.					Second brood.				
	Number of vines.	Number of clusters.	Total berries.	Infested berries.	Infestation.	Number of vines.	Number of clusters.	Total berries.	Infested berries.	Infestation.
					Per cent.					Per cent.
I.....	20	1,024	29,036	572	1.97	15	768	21,760	849	3.9
II.....	20	1,132	31,314	572	2.71	15	849	23,489	963	4.1
Check A.....	20	1,124	30,568	2,404	7.86	15	843	22,926	3,372	14.8
III.....	20	1,330	38,676	375	.97	15	997	29,066	313	1.2
IV.....	20	1,192	41,107	124	.30	15	894	30,830	68	.23
Check B.....	20	1,051	29,567	1,943	6.57	15	788	22,175	3,925	17.7
Check C.....	20	832	21,356	1,743	8.16	15	624	16,016	1,399	46.2

On all sprayed plats where poison with adhesive had been applied with "trailers" the control was effective. Plats I and II on which arsenate of lead (paste) had been applied at the rate of 3 pounds to 50 gallons of liquid were infested more heavily than Plats III and IV, on which arsenate of lead at the rate of 5 pounds to 50 gallons had been applied. The infestation was naturally heavier on the west side, however, as is shown by a comparison of the unsprayed plats. Double spraying appeared to reduce the infestation but not enough to offset the extra cost of application.

EXPERIMENT IN THE MILLER AND CARLBURG VINEYARD, NORTH EAST, PA., 1915.

The experimental plat in this vineyard included 64 rows covering about 10 acres. It was divided into 10 plats of 6 rows each, the 4 remaining rows being left for check. This plat was surrounded on

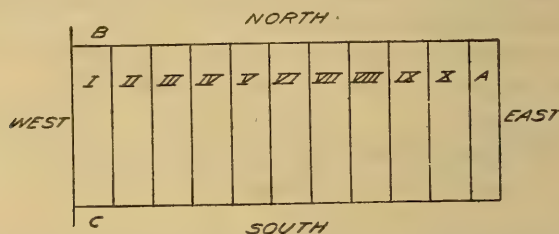


FIG. 4.—Diagram showing arrangement of experimental plats in the vineyard of Messrs. G. H. Miller and A. I. Carlborg, North East, Pa., 1915. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

all sides by vineyard, two parts of which were used as checks also. The arrangement of plats is shown in the diagram (fig. 4). Spraying operations for both first and second applications in this vineyard were interrupted and delayed by frequent rains.

TABLE 8.—*Spray mixtures used and methods and dates of application in experimental plats, Miller and Carlborg vineyard, North East, Pa., 1915.*

Plot No.	Dates of spraying.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Fish-oil soap.	Flour paste.	Nicotine sulphate.	Water.	Method of application.
			Lime.	Copper sulphate.						
		Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pints.	Gallons.	
I.....	July 2, 15	3	3	3	1				50	"Trailers."
II.....	July 2, 15	5	3	3		2			50	Do.
III.....	July 2, 15	3				2			50	Do.
IV.....	July 3, 16	3	3	3	1				50	Do.
V.....	July 3, 16	3	3	3		2			50	Do.
VI.....	July 3, 16	3	3	3	1			$\frac{1}{2}$	50	Do.
VII.....	July 3, 17		3	3	1			$\frac{1}{2}$	50	Do.
VIII.....	July 5, 17	3	3	3			2		50	Do.
IX.....	July 5, 17	3	3	3					50	Do.
X.....	July 5, 17	3	3	3		2			50	"Set nozzles."

¹ Rain followed immediately after the second spray application on this plat and apparently washed off most of the spray.

TABLE 9.—*Percentage of infestation in experimental plats, Miller and Carlborg vineyard, North East, Pa., 1915.*

Plat No.	First brood.					Second brood.				
	Number of vines.	Number of clusters.	Total berries.	Infested berries.	Infestation.	Number of vines.	Number of clusters.	Total berries.	Infested berries.	Infestation.
I.....	25	601	14,028	450	<i>Per ct.</i> 3.21	20	481	10,822	847	<i>Per ct.</i> 7.91
II.....	25	544	12,550	414	3.29	20	435	9,640	951	9.86
III.....	25	492	11,235	519	4.53	20	397	9,088	2,887	31.77
IV.....	25	460	13,692	343	2.51	20	368	10,956	432	3.94
V.....	25	575	13,705	289	2.11	20	460	10,960	967	9.56
VI.....	25	796	19,544	479	2.45	20	637	15,625	1,188	7.60
VII.....	25	712	22,736	1,264	5.99	20	570	16,587	5,523	33.31
VIII.....	25	661	18,508	795	4.18	20	529	14,783	2,793	18.89
IX.....	25	561	16,269	901	5.53	20	459	13,005	2,758	21.05
X.....	25	716	21,480	1,024	4.53	20	513	15,441	3,152	20.41
Check A.....	25	695	20,850	1,013	4.86	20	556	14,430	3,958	28.80
Check B.....	25	792	23,882	3,533	14.87	20	654	19,135	11,803	61.67
Check C.....						10	340	9,380	4,710	50.21

In spite of the exceedingly adverse weather conditions at the time of spraying, all plats but one on which arsenate of lead with soap had been applied twice with "trailers" (Plats I, II, IV, V, and VI) showed a satisfactory reduction of the grape-berry moth from a commercial standpoint. In one plat where rain followed immediately after the second spray application (Plat III) the results must be disregarded. The rain also probably reduced the efficiency of control in Plat II, which was sprayed just before Plat III, and to a less degree may have affected others; but the results showed that when the spray had time to dry on the grape berries before rain, a fairly satisfactory control could be secured. Failure to control resulted in plats where spray was applied with "set nozzles" instead of "trailers" (Plat X), where the soap was omitted from the spray mixture (Plat IX), and where flour paste was used as adhesive instead of soap (Plat VIII). Bordeaux mixture and soap were used without arsenate of lead (Plat VII) and no effect, repellent or insecticidal, was noted. Nicotine sulphate appeared to add nothing to the effectiveness of the solution (Plats V and VI). Laundry soap (Plats I, IV, and VI) and fish-oil soap (Plats II and V) were both used apparently without distinct advantage for either. The plat sprayed with 5 pounds of arsenate of lead (paste) to 50 gallons of liquid (Plat II) was much more heavily infested than the plat sprayed with only 3 pounds of arsenate of lead (paste) to 50 gallons (Plat IV), but as the second application of spray on Plat II was closely followed by rain the infestation in this plat was probably also somewhat heavier naturally. (Compare check plats B and C with A.)

EXPERIMENT IN THE MOORHEAD VINEYARD, MOORHEADVILLE, PA., 1915.

The experimental work in the Moorhead vineyard was conducted in the same section as in 1914, but the arrangement of plats was somewhat changed. The plat that had the lightest infestation was chosen as check, while the check of the 1914 season was sprayed. The adjacent sections of the vineyard were sprayed once by the owner, soon after July 1, with arsenate of lead (paste), 3 pounds, and Bordeaux mixture, 50 gallons, to control the grape rootworm; the spray was applied with "set nozzles." Counts were made from these sections adjacent

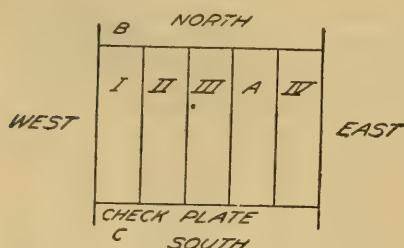


FIG. 5.—Diagram showing arrangement of plats in the vineyard of Mr. J. M. Moorhead, Moorheadville, Pa., 1915. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

to the experimental block and they are recorded as checks, B and C. The arrangement of plats is shown by the diagram (fig. 5).

TABLE 10.—*Spray mixtures used and methods and dates of application in experimental plats, Moorhead vineyard, Moorheadville, Pa., 1915.*

Plat No.	Dates of spraying.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Nicotine sulphate.	Water.	Method of application.
			Lime.	Copper sulphate.				
I.....	July 1, 20..	Pounds. 3	Pounds. 3	Pounds. 3	Pounds. 1	Pints. -----	Gallons. 50	Sprayer ("trailer") driven in alternate alleys.
II.....	July 1, 20..	5	3	3	1	-----	50	Every alley.
III.....	July 1, 20..	3	3	3	1	4	50	Alternate alleys.
IV.....	July 1, 21..	3	3	3	1	-----	50	Every alley.

TABLE 11.—*Percentage of infestation in experimental plats, Moorhead vineyard, Moorheadville, Pa., 1915.*

Plat No.	Number of vines.	Number of clusters.	Total berries.	First brood.		Second brood.	
				Infested berries.	Infestation.	Infested berries.	Infestation.
					Per cent.		Per cent.
I.....	20	820	29,130	90	0.31	1,099	3.77
II.....	20	975	34,450	112	.32	717	2.08
III.....	20	726	22,411	49	.22	943	4.21
Check A.....	20	975	25,512	903	3.54	4,860	19.05
IV.....	20	813	26,350	141	.54	1,070	4.06
Check B.....	20	785	21,951	715	3.25	4,997	22.81
Check C.....	20	756	22,478	822	3.65	7,736	34.86

The final counts show that the grape-berry moth had been controlled in all sprayed plats. In this respect they contrast sharply with the previous season's results in the same vineyard. The only essential differences between the treatments of this season and those of the previous one were the addition of soap to the spray mixture and the application of the spray with "trailers" instead of with "set nozzles."

The results further indicate that 3 pounds of arsenate of lead (paste) was practically as effective as 5 pounds to 50 gallons of liquid, and that no special advantage or injury resulted from the addition of nicotine sulphate to the spray mixture. Also that drawing the sprayer in every alley and each rodman spraying only one side of a row at a time had no advantage over driving up alternate alleys with each rodman spraying both sides of a row at one time.

SPRAYING EXPERIMENTS IN 1916.

Confirmation of the 1915 results was the most important feature of the season's work. Although infestation by the grape-berry moth was much heavier, the season was more favorable for work and the control measures were more effective.

EXPERIMENTS IN THE BARTLETT VINEYARD, NORTH EAST, PA., 1916.

The experimental work in Mr. A. P. Bartlett's vineyard was conducted in two sections differing in distribution of the berry moth. In both sections the rows ran north and south, but the checks were arranged differently. In the upper section the 1915 infestation was

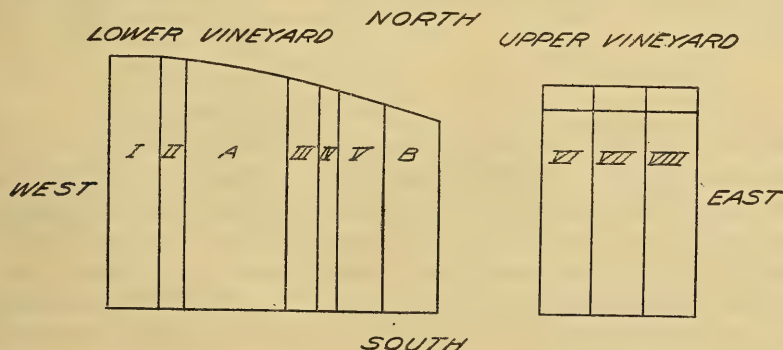


FIG. 6.—Diagram showing arrangement of experimental plats in vineyard of Mr. A. P. Bartlett, North East, Pa., 1916. In the lower vineyard the sprayed plats are marked with Roman numerals and the check plats are lettered. (Original.)

much the heavier on the west side, consequently the checks were not chosen in the usual way but instead a transverse check of the end 6 vines on all rows was left unsprayed. The arrangement of plats is shown by the diagram (fig. 6).

TABLE 12.—*Spray mixtures used and method and dates of application in experimental plats, Bartlett vineyard, North East, Pa., 1916.*

Plat No.	Date sprayed.	Arsenate of lead (powder).	Bordeaux mixture.		Laundry soap.	Resin fish-oil soap.	Potash fish-oil soap.	Water.	Method of application.
			Lime.	Copper sulphate.					
I	July 12	Pounds. 1½	Pounds. 3	Pounds. 3	Pounds. 1	-----	-----	Gallons. 50	"Trailers."
II	Aug. 22	2½	3	3	-----	1	-----	50	Do.
III	July 6, 25	1½	3	3	-----	1	-----	50	Do.
IV	July 6, 25 and Aug. 12.	1½	3	3	1	-----	-----	50	Do.
V	July 5, 21	1½	3	3	1	-----	-----	50	Do.
IV	July 6, 21	2½	3	3	1	-----	-----	50	Do.
VII	July 5, 21	1½	-----	-----	1	-----	-----	50	Do.
VIII	July 5, 22	1½	3	3	-----	-----	2	50	Do.

TABLE 13.—*Percentage of infestation in experimental plats, Bartlett vineyard, North East, Pa., 1916.*

Plat No	Number of vines.	Number of clusters.	Total. berries.	First brood.		Second brood.	
				Infested berries.	Infesta- tion.	Infested berries.	Infesta- tion.
<i>Lower.</i>					<i>Per cent.</i>		<i>Per cent.</i>
I.....	20	532	17,556	1,708	9.72	2,970	16.92
II.....	20	424	12,720			2,486	19.97
Check A.....	20	415	12,450	858	6.64	6,913	55.53
III.....	20	389	11,281	228	2.02	243	2.14
IV.....	20	390	11,700			81	.68
V.....	20	411	11,508	145	1.26	182	1.57
Check B.....	20	460	12,420			10,909	79.72
<i>Upper.</i>							
VI.....	20	474	15,168	320	2.11	768	5.06
Check VI.....	6	111	3,330	717	21.53	3,158	94.83
VII.....	20	681	18,068	199	1.10	724	4.01
Check VII.....	6	200	7,200	452	6.27	6,380	88.74
VIII.....	20	512	14,336	69	.48	67	.47
Check VIII.....	6	214	6,848	263	3.84	1,764	25.76

The final counts in this vineyard showed satisfactory results in all plats on which two applications of arsenate of lead with soap had been made (Plats III, V, VI, VII, and VIII). Where, in addition to these two applications, a third application was made, directed solely against the second brood, the percentage of infested fruit was slightly reduced, but since the result was so satisfactory with two sprays (compare Plat IV with III and V) an extra or third application was unnecessary. As an additional disadvantage, the fruit thus sprayed was badly stained at harvest time. A single application made at the time when the grape berries were just touching (Plat I) effected a marked reduction of infestation, as did a later single application directed solely against the second brood (Plat II), but in both plats the results were far from satisfactory. Any late application is open thus to objection because of staining the fruit at the approaching harvest. Three adhesives, laundry soap (Plat V), resin fish-oil soap (Plat III), and fish-

oil soap without resin (Plat VIII), were used. The difference in infestation in these plats was so slight that it is not worthy of special consideration. Resin fish-oil soap solution spread rapidly and could be applied most easily. Arsenate of lead when used at the rate of $2\frac{1}{2}$ pounds (powder) to 50 gallons of liquid (Plat VI) did not appear more effective than when used at the rate of $1\frac{1}{2}$ pounds to 50 gallons. The solution in which Bordeaux mixture was omitted (Plat VII) was practically as effective as any other, although slight burning followed its application.

EXPERIMENT IN THE SOUTHWICK VINEYARD, NORTH EAST, PA., 1916.

A plat of 28 rows, 9 rows to the acre, was chosen for experimental purposes in this vineyard. An unsprayed check of 8 rows was left in the middle of the plat. On one side were two sprayed plats of 6 rows each, and on the other side two plats of 4 rows each. The rest of the vineyard section on either side of the experimental block, although sprayed for the grape rootworm by the owner, also served as a check. The arrangement of these plats is shown by the diagram (fig. 7).

During the season of 1915 this section had been heavily infested, from 30 to 40 per cent, with a tendency for the infestation to be heaviest at the north end.

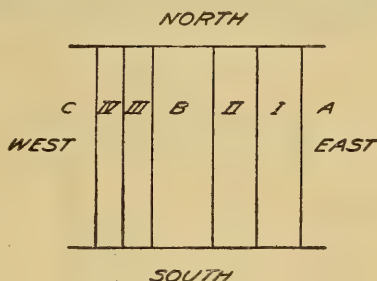


FIG. 7.—Diagram showing arrangement of experimental plats in the vineyard of Mr. B. T. Southwick, North East, Pa., 1916. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

TABLE 14.—*Spray mixtures used and methods and dates of application, Southwick vineyard, North East, Pa., 1916.*

Plat No.	Date sprayed.	Arsenate of lead (powder).	Bordeaux mixture.		Nicotine sulphate, 40 per cent. ¹	Laundry soap.	Water.	Method of application.
			Lime.	Copper sulphate.				
		Pounds.	Pounds.	Pounds.	Pints.	Pounds.	Gallons.	
I.....	July 10, 24.	$1\frac{1}{2}$	3	3	$\frac{1}{2}$	1	50	"Trailers."
II.....	do	$2\frac{1}{2}$	3	3	$\frac{1}{2}$	1	50	Do.
III.....	July 24.	$1\frac{1}{2}$	3	3	$\frac{1}{2}$	1	50	Do.
IV.....	July 10, 24.	$1\frac{1}{2}$	3	3	$\frac{1}{2}$	1	50	"Set nozzles" first application, "Trailers" second.

¹ Last application only.

TABLE 15.—Percentage of infestation in experimental plats, Southwick vineyard, North East, Pa., 1916.

Plat No.	Number of vines.	Number of clusters.	Total berries.	First brood.		Second brood.	
				Infested berries.	Infestation.	Infested berries.	Infestation.
					<i>Per cent.</i>		<i>Per cent.</i>
Check A.....	20	609	16,443	2,866	17.43	11,635	70.76
I.....	20	570	15,960	565	3.41	1,339	8.43
II.....	20	638	19,778	597	3.02	835	4.22
Check B.....	20	623	15,575	2,129	13.61	11,706	75.16
III.....	20	585	14,625	1,364	9.32	4,966	33.95
IV.....	20	584	16,936	995	5.87	3,242	19.13
Check C.....	20	608	15,200	1,073	7.06	9,963	65.65

The final counts in this vineyard showed that the grape-berry moth had been controlled in the plat where two applications with "trailers" had been made, using arsenate of lead (powder) at the rate of $2\frac{1}{2}$

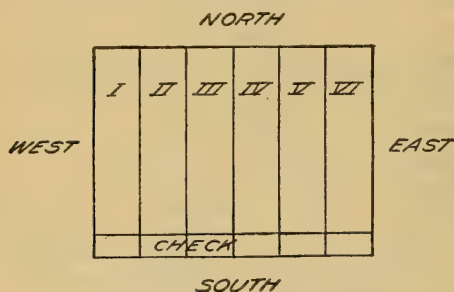


FIG. 8.—Diagram showing arrangement of experimental plats in the vineyard of Mr. J. M. Moorhead, Moorheadville, Pa., 1916. (Original.)

pounds to 50 gallons with an adhesive (Plat II). This was in the face of a very heavy infestation in the checks. In contrast to the results in all other vineyards, in the plat in which $1\frac{1}{2}$ pounds of arsenate of lead (powder) was used the final count was distinctly less satisfactory (Plat I). This difference was conspicuous only at the north end of the vineyard, where the infestation in the checks was practically total and where several eggs had been deposited on a majority of the berries. It should be noted that the contrast was not apparent until the second-brood counts were made, and the first-brood infestation was about the same in both plats. An unusually large percentage of second-brood larvæ found in Plat I were very late, indicating that the early second brood had failed to enter the berries. This would indicate that the two amounts of poison were equally effective for some time, but that the higher amount withstood the weathering better.

Two applications (1) with "set nozzles" and (2) with "trailers" (Plat IV) were partially effective, though not satisfactory. A single application with "trailers" when the berries were just touching (Plat III) was entirely unsatisfactory.

EXPERIMENT IN THE MOORHEAD VINEYARD, MOORHEADVILLE, PA., 1916.

An experimental plat of 48 rows, 8 rows per acre, was chosen in this vineyard. It was divided into 6 plats of 8 rows each. During the season of 1915 the infestation was heavy, 30 to 35 per cent of the berries being "wormy," with a tendency for heaviest infestation at the west side. Accordingly a transverse check of seven unsprayed vines at the end of each row was left. The arrangement of plats is shown by the diagram (fig. 8).

TABLE 16.—*Spray mixture used and methods and dates of application, Moorhead vineyard, Moorheadville, Pa., 1916.*

Plat No.	Date sprayed.	Arsenate of lead (powder.)	Bordeaux mixture.		Laundry soap.	Potash fish-oil soap.	Soft soap.	Water.	Method of application.
			Lime.	Copper sulphate.					
I.....	July 8, 19	Pounds. 1½	Pounds. 3	Pounds. 3	Pounds. 1	Pounds.	Pounds.	Gallons. 50	Trail- ers."
II.....	..do....	2½	3	3	1			50	Do.
III.....	July 8, 20	1½	3	3		2		50	Do.
IV.....	..do....	1½	3	3	1			50	"Setnoz- zles," first appli- cation; "trail- ers"
V.....	..do....	1½	3	3			1	50	second. "Trail- ers."
VI.....	July 20.	1½	3	3	1			50	Do.

TABLE 17.—*Percentage of infestation in experimental plats, Moorhead vineyard, Moorheadville, Pa., 1916.*

Plat No.	Number of vines.	Number of clusters.	Total berries.	First brood.		Second brood.	
				Infested berries.	Infestation.	Infested berries.	Infestation.
I.....	20	850	29,750	243	<i>Per cent.</i> 0.81	1,752	<i>Per cent.</i> 5.88
Check I.....	6	253	9,108	406	4.45	3,812	41.85
II.....	20	675	23,625	154	.65	949	4.02
Check II.....	6	226	8,136	297	3.65	2,997	36.83
III.....	20	709	23,397	152	.64	806	3.15
Check III.....	6	195	7,410	340	4.57	2,848	38.43
IV.....	20	638	19,778	163	.82	1,307	6.61
Check IV.....	6	235	8,930	345	3.86	2,443	27.33
V.....	20	703	23,902	190	.79	4,605	19.60
Check V.....	6	224	8,064	174	2.15	2,741	33.99
VI.....	20	709	20,561	333	1.61	1,079	5.25
Check VI.....	6	154	4,312	86	1.99	1,010	23.39

The final counts showed satisfactory results in plats where two applications with "trailers" were made with poison and laundry or fish-oil soaps (Plats I, II, III). Fish-oil soap without resin as well as laundry soap was an effective adhesive, fish-oil soap having the advantage. A "soft soap" was also used (Plat V), but proved a

very poor adhesive. Arsenate of lead at the rate of $2\frac{1}{2}$ pounds (powder) to 50 gallons of liquid (Plat II) appeared to be little more effective at the increased strength than when used at the rate of $1\frac{1}{2}$ pounds to 50 gallons (Plat I).

Plats where the first application was made with "set nozzles" (Plat IV) and where it was omitted altogether (Plat V) showed a fairly satisfactory reduction of infestation. It should be noted that the infestation in the checks in these two plats was not as heavy as that in the checks adjacent to Plats I, II, and III.

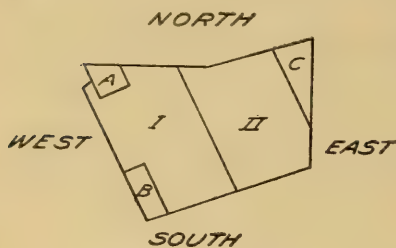


FIG. 9.—Diagram, showing the arrangement of experimental plats in the vineyard of Mr. M. D. Phillips, North East, Pa., 1916. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

infestation unsprayed checks were left in each of the three corners. The arrangement of plats is shown in the diagram (fig. 9).

TABLE 18.—*Spray mixtures used and methods and dates of application, Phillips vineyard, North East, Pa., 1916.*

Plat No.	Dates sprayed.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Water.	Method of application.
			Lime.	Copper sulphate.			
I.....	July 5 and 22..	Pounds. 5	Pounds. 3	Pounds. 3	Pounds. 1	Gallons. 50	"Trailers." Do.
II.....	July 5 and 22..	3	3	3	1	50	

TABLE 19.—*Percentage of infestation in experimental plats, Phillips vineyard, North East, Pa., 1916.*

Plat No.	Number of clusters.	Total berries.	First brood.		Second brood.	
			Infested berries.	Infestation.	Infested berries.	Infestation.
				<i>Per cent.</i>		<i>Per cent.</i>
I.....	400	15,200	436	2.87	479	3.15
II.....	400	16,000	107	.67	142	.89
Check A.....	200	7,200	423	5.88	5,135	71.32
Check B.....	200	7,600	1,186	15.61	6,114	80.45
Check C.....	200	8,000	289	3.11	4,034	50.43

Results in this vineyard showed that spraying will control the grape-berry moth fully as well in the very compact clusters of the Niagara grapes as in the less compact Concord. The test was thorough, as shown by the heavy infestation in the checks. Arsenate of lead used at the rate of 5 pounds (paste) to 50 gallons of liquid (Plat I) did not appear to have any advantage over 3 pounds to 50 gallons (Plat II).

THE SPRAY MIXTURE.

ARSENATE OF LEAD, AMOUNT NECESSARY.

Arsenate of lead, either as paste or as powder, was the insecticide used in all field experiments. In all instances but one, when used at the rate of 3 pounds, paste, or $1\frac{1}{2}$ pounds, powder, to 50 gallons of liquid, the amount was sufficient to reduce the grape-berry moth satisfactorily. During the seasons of 1915 and 1916 at least one plat was sprayed with poison at the above rate, and one other plat was sprayed under conditions as nearly the same as possible except that the amount of poison was increased to 5 pounds of paste or $2\frac{1}{2}$ pounds of powder to 50 gallons of liquid. In all instances except the one referred to no distinct advantage was shown in favor of the higher amount, while in two of the vineyards the plats sprayed with the higher amount were actually the more heavily infested. The differences in results that did appear were usually slight and could be accounted for largely by variation of infestation. The comparative value of the two amounts of poison as it appeared in the different vineyards is summarized in Table 20.

TABLE 20.—*Relative efficiency of arsenate of lead at the rate of 3 pounds and 5 pounds (paste) to 50 gallons of liquid.*

Amount of arsenate of lead.	Treatments common to all plats.	Years tried.	Number of vineyards.	Number of plats.	Infested grape berries.					
					Best plat.	Adjacent check.	Poor-est plat.	Adjacent check.	Average of all plats.	Average of all adjacent checks
3 pounds paste or $1\frac{1}{2}$ pounds powder to 50 gallons of water.	Laundry soap, 1 pound, Bordeaux mixture (3-3 formula).	1915, 1916	7	7	<i>Per ct.</i> 0.89	<i>Per ct.</i> 50.43	<i>Per ct.</i> 8.43	<i>Per ct.</i> 75.16	<i>Per ct.</i> 4.12	<i>Per ct.</i> 50.03
The same as above. Poor-est plat eliminated.	50 gallons applied twice with "trailers."	1915, 1916	6	6	-----	-----	-----	-----	3.41	49.17
5 pounds paste or $2\frac{1}{2}$ pounds powder to 50 gallons of water.	-----	1915, 1916	6	16	3.15	75.16	5.06	94.83	3.34	54.90

¹ Plat II, Miller and Carlburg vineyard, is not included in this average because the results were prejudiced by rain.

Table 20 indicates that as a rule there is practically no difference in effectiveness between the two amounts of poison. However, in

the Southwick vineyard, 1916 (Plats I and II), the results in the plat sprayed with the higher amount appeared so much better in the final counts that the result could hardly be accounted for by variable infestation. Moreover, checks on either side showed that very little variation existed. In this vineyard at one end, although not throughout the vineyard, the checks showed an infestation very near to total, and probably enough moths had emerged to have totally infested a crop several times as heavy. Under such conditions of extremely heavy infestation the higher amount of poison was more effective. As previously stated in the discussion of results in the Southwick vineyard, the two amounts of poison were apparently equally effective when the first counts were made, but the higher amount withstood the weathering better and was more effective against the late second brood.

ADHESIVES.

The necessity of adding adhesives to the spray mixture became apparent to the writer in the experiments in 1914. It was readily observed that the spray solutions from which an adhesive was absent did not adhere to the waxy skin of the grape berries, and this was undoubtedly one of the chief reasons for the failure to control the grape-berry moth during that season. The solutions to which soap was added appeared to adhere much better, but since this was used only in the last application a definite contrast in the final count was not shown. The counts in plats where soap had been added to the spray solution and applied with "trailers," however, when compared with counts in the nearest checks are consistently better than the others.

The effect of applying a spray mixture without adhesives was specifically demonstrated in 1915 by a comparison of the results in Plats V and IX in the Miller and Carlburg vineyard, pages 18-19.

TABLE 21.—*Relative effectiveness of spray mixtures with various adhesives and without adhesive.*

(Treatments common to all plats: Arsenate of lead, 3 pounds of paste or 1½ pounds of powder; Bordeaux mixture (3-3-50 formula) applied twice with "trailers.")

Kind of adhesive used.	Years tried.	Number of vineyards.	Number of plats.	Infested grape berries.					
				Best plat.	Adjacent check.	Poor-est plat.	Adjacent check.	Average of all plats.	Average of all adjacent checks.
				Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Resin fish-oil soap.....	1916	1	1	.....	.....	.....	.....	2.14	55.53
Fish-oil soap (without resin).	1916 only.	2	2	.....	.....	.....	.....	1.97	31.29
Do.	1915, 1916	3	3	0.47	25.76	7.91	65.94	3.95	42.84
Laundry soap.....	1916 only.	4	4	.....	.....	.....	.....	4.14	61.79
Do.	1915, 1916	7	7	.89	50.43	8.43	75.16	4.12	50.03
Soft soap.....	1916	1	1	.....	.....	.....	.....	19.60	33.99
Flour paste.....	1915	1	1	.....	.....	.....	.....	18.89	28.80
No adhesive.....	1915	1	1	.....	.....	.....	.....	21.05	28.80



SPRAYING AGAINST THE GRAPE-BERRY MOTH.

Comparative spreading qualities in spray mixture of a laundry soap (fig. 1) and a resin fish-oil soap (fig. 2). (Original.)

From Table 21 it may be seen that fish-oil and laundry soaps used in the seasons of 1915 and 1916 were both effective as adhesives and that soft soap and flour paste were unsatisfactory. (See Pl. VI.) The advantage of one soap over another, as shown in the final counts, was usually so slight that it can not be considered significant.

At the time of application resin fish-oil soap appeared at best advantage. It was a better spreader than any of the others and consequently made the work faster and easier. It was used only in the Bartlett vineyard during the season of 1916. The potash fish-oil soap without resin also spread better than laundry soap. Potash fish-oil soap was used in 1915 in the Miller and Carlborg vineyard and in 1916 in the Moorhead and Bartlett vineyards.

The following analysis of the resin fish-oil soap used was made by the Bureau of Chemistry:

Water, 25.7 per cent.

Fatty and resin anhydrides, 68 per cent.

Sodium oxide, Na_2O , 4.3 per cent.

Undetermined, 2 per cent.

Laundry soap if carefully used is practically as effective and adhesive as the fish-oil soaps, but it has two distinct disadvantages, (1) it is a slower and a poorer spreader than fish-oil soaps, and (2) different makes of soap and even different lots of soap of the same make vary. In the experimental work each brand of soap was tried on a few vines with a hand sprayer before it was used in commercial experiments. If the vineyardist finds it necessary to rely on laundry soaps for an adhesive, this precaution would be advisable.

All of the laundry soaps that proved satisfactory were yellow resin soaps. Some of the so-called white soaps containing no resin were tried with a hand sprayer but lacked adhesive qualities and were not used in any field experiments.

Cutting the laundry soap and allowing it to dry out before using it in the spray mixture seemed to impair its sticking as well as its spreading qualities seriously.

A soft soap from a rendering factory also was tried, but gave negative results both as an adhesive and as a spreader. This was observed readily at the time of application, and the result is shown clearly in the final counts. (Moorhead vineyard, Plat V, 1916.)

Flour paste although a good spreader was an unsatisfactory adhesive, because it washed off with the first rain. (Miller and Carlborg vineyard, Plat VIII, 1915.)

When soap in the spray mixture is not dissolved thoroughly, clogging of the spray apparatus is likely to follow. Hot water was found necessary for quickest results. If the sprayer engine is water cooled, hot water from the water jacket can be used satisfactorily for this purpose.

Amount of adhesive necessary.—Resin fish-oil soap or laundry soap used at the rate of 1 pound to 50 gallons of liquid gave good results as a “sticker” and spreader. Potash fish-oil soap without resin was used at the rate of 2 pounds to 50 gallons of liquid.

NICOTINE SULPHATE.

Forty per cent nicotine sulphate was utilized in sprays every year in some of the vineyards against the grape leafhopper. This substance was used at the rate of 1 part to 1,600 parts of liquid in the last grape-berry moth spray. In 1915 it was used in both of the applications against the berry moth. In none of the plats on which it was used was there any indication that nicotine sulphate added to or detracted from the value of the spray mixture, so far as grape-berry moth control was concerned.

RELATION OF FUNGICIDES.

Bordeaux mixture had no insecticidal or repellent value, so far as the grape-berry moth was concerned. (Miller and Carlborg vineyard, Plat VII, 1915.) However, the addition of this fungicide seemed to be advantageous. Besides reducing the danger of burning by the arsenate of lead and soap combination it gave to the spray mixture physical qualities which lessened the tendency to collect on the lower surface of the berry.

The relation of neutral acetate of copper to arsenate of lead and soap was tried in an experiment on a small scale. It was thought that this nonstaining fungicide might be substituted for Bordeaux mixture if an August spray were adopted. One pound of neutral acetate of copper and 1 pound of soap to 50 gallons of water were mixed and applied to a few vines. The result was unsatisfactory. No injury to the foliage resulted, but the soap and neutral copper acetate in combination stained the grapes fully as objectionably as the soap and Bordeaux combination.

It had been demonstrated previously that the Burgundy mixture should not be used in combination with an arsenical, and it was not tried.

LIME.

When for any reason it was desired to omit Bordeaux mixture from the spray combination of arsenate of lead and soap, lime was added at the rate of 1 pound to 50 gallons of liquid.

INJURY DUE TO SPRAYING.

Combinations of arsenate of lead and soap with Bordeaux mixture or lime caused no injury to foliage in any of the three seasons of experimental work. If “nicotine sulphate 40 per cent” at the rate of 1 part to 1,600 parts of liquid was added to this solution it also was

applied safely. However, the combination of arsenate of lead and soap alone produced slight burning of foliage in 1916. (Bartlett vineyard, Plat VII.)

No serious staining of fruit occurred except when the second-brood spray was applied in August in 1916. This was much reduced by using the arsenate of lead and soap with lime instead of with Bordeaux mixture.

METHOD OF APPLICATION.

The first season's experiments clearly demonstrated the difficulty in covering grape clusters by the "set-nozzles" applications. This was particularly inadequate at the last application, at which time the foliage is very heavy, and pressure up to 250 pounds was not effective. The use of "trailers" on a few plats for the last application suggested the complete change of method which followed the next season.

A specific demonstration of the inadvisability of depending on "set nozzles" as a means of applying spray was shown in 1915 by the contrast between Plats I and X in the Miller and Carlborg vineyard.

The necessity of using "trailers" was so satisfactorily established in the first two seasons that during 1916 "set nozzles" were not used in both applications in any plats. However, in the Moorhead vineyard, Plat IV, and in the Southwick vineyard, Plat IV, "set nozzles" were tried for the first application. In the former, at the time of the first application, the results were reasonably satisfactory, although not the best. In the latter vineyard the foliage was very heavy when "set nozzles" were used, and the failure to cover the clusters with spray was obvious. The reduction of infestation that resulted should be credited largely to the last application, which was made with "trailers."

The relative efficiency of "set nozzle" and "trailer" methods of application and a combination of these methods is shown in Table 22.

TABLE 22.—*Relative efficiency of "trailer" and "set nozzle" methods of application.*

(Treatments common to all plats: Arsenate of lead, 3 pounds paste or 1½ pounds powder; laundry soap, 1 pound; Bordeaux mixture (3-3-50) applied after falling of blossoms and when grape berries were just touching.)

Method of application.	Years tried.	Number of vineyards.	Number of plats.	Infested grape berries.					
				Best plat.	Adjacent check.	Poor-est plat.	Adja-cent check.	Average of all plats.	Average of all checks.
"Trailers," 2 applications.	1915, 1916	7	7	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
"Set nozzles," 1 application; "trailers," 1 application.				0.89	50.43	8.43	75.16	4.12	50.03
"Set nozzles," 2 applications.	1916	2	2	6.61	38.43	19.13	65.65	12.87	52.04
"Set nozzles," 2 applications.	1915	1	1	20.41	28.80	20.41	28.80	20.41	28.80

Usually when "trailer" applications were made the sprayer was driven only in every other alley between the grape rows, each rodman spraying both sides of his row on the same trip.

During the season of 1915, in the Moorhead vineyard, Plats II and IV, the sprayer was driven in every alley, each rodman spraying only one side of a row on each trip. While it was easier to cover the foliage by this method, it was slower and it showed no distinct advantage over the usual method, in controlling the berry moth. It was given no further trial. Which of the two methods is best is probably a matter of individual preference.

Careful work was an absolute necessity for successful "trailer" applications. While the responsibility rested chiefly with the rodmen, unless the driver was careful about gathering up the hose and at the same time allowing the rodmen time to finish spraying each vine the work was handicapped greatly. It was necessary also that the rodmen should make an effort to cover each cluster or the advantage of "trailers" over the strictly mechanical method was lost.

TIME AND NUMBER OF APPLICATIONS.

The most satisfactory spray schedule was as follows: The first application to be made immediately after the falling of the bloom; and the second application about two weeks later, at the time when the berries are just touching. This proved effective both in 1915 and in 1916, and was the schedule used in the majority of plats.

A single application at the time the berries were just touching reduced the infestation greatly, but hardly offered satisfactory results. It was tried only in the season of 1916. This spray is intended for late first-brood larvæ, and enough of the poison will remain on the berries, at the time of the hatching of eggs of the second brood, greatly to reduce this brood as well. The effect of this spray against the second brood is shown by referring to the counts in Bartlett (lower) vineyard, Plat I, in comparison with the adjacent Check Plat A. Plat I was naturally more heavily infested than was Check Plat A, as the first-brood count showed that it had about 50 per cent more infested berries than did "A." On the other hand the final count showed the percentage of infestation in Check Plat A to be three times as heavy as that in Plat I. Similar final results are shown in Southwick vineyard, Plat IV. The results in the Moorhead vineyard, Plat VI, would indicate that in case of light infestation this one application might control the berry moth satisfactorily.

In 1916 a single application, made on August 12 and aimed directly against the second brood, also reduced the infestation considerably, as shown in Bartlett vineyard Plat II, although the counts did not appear as favorable as the single earlier application previously men-

tioned as being made when the berries were just touching. This was probably due to the fact that the absence of the early application permitted all of the first brood to enter the berries and heavier oviposition later resulted. Furthermore, dependence upon an application as late as August 12, alone, is open to objection even if the second-brood control was very good, because infestation by the first brood will usually seriously thin out the clusters, and too, the spray remains longer on the berries, leaving them seriously stained at harvest time. This application is harder to make than is the earlier one because the foliage at the later date is much heavier. The value of the application is largely that of an emergency measure, at a time when the first brood has not been controlled.

A three-spray schedule was tried in Plat IV of the Bartlett (lower) vineyard. The infestation was less than in Plats III and V, which had been sprayed twice. However, in this instance the difference was not of commercial importance and would not pay for the extra application, and the fruit was stained so badly by the last application as to reduce materially its value on the basket market. This third application could be of value in this region only under extraordinary conditions, when faulty work or lack of spray materials and labor or unfavorable weather had prevented the control of the first brood.

A comparison of the results of different spray schedules is given in Table 23. The average infestation of plats where two applications were made was distinctly heavier than was the infestation in the one plat where three applications were made. It should be noted, however, that where the plats sprayed two and three times were adjacent in the same vineyard, the difference in infestation was very slight.

It also shows that the single application may produce fair control if the infestation is light, but that on the whole dependence on a single application is unsatisfactory.

A spray application before the grapes blossomed, followed by the usual two applications after the falling of the blossoms, was tried in one plat in each vineyard in 1914. No beneficial results of this spray could be noted when the final counts were made. The importance of this spray was brought into question soon after its application, for very few larvæ were found in the clusters before the next was applied. Even had they been numerous at that time, the "preblossom spray" could hardly have been effective, as practically all of the poison that did adhere to the clusters when applied fell off a few days later with the flower caps.

This early spray was applied again in 1915 in all three vineyards, but since practically no larvæ were found until the blossoms fell, these plats were discarded.

TABLE 23.—*Relative efficiency of different times and numbers of applications.*

Time and number of applications.	Treatments common to all plats.	Years tried.	Number of vine-yards.	Number of plats.	Infested grape berries.					
					Best plat.	Adja-cent check.	Poor-est plat.	Adja-cent check.	Aver-age of all plats.	Aver-age of all adja-cent checks.
Two applications after blossoms have fallen and when grape berries are touching.	Arsenate of lead, 3 pounds paste or 1½ pounds powder; laundry soap, 1 pound; Bordeaux mixture (3-3-50), applied with "trailers."	1915, 1916	7	7	P. ct. 0.89	P. ct. 50.43	P. ct. 8.43	P. ct. 75.16	P. ct. 4.12	P. ct. 50.03
Two applications, same as above, including only plat adjacent to that sprayed 3 times.	do.....	1916	1	1	1.57	79.72	1.57	79.72	1.57	79.72
Three applications, 2 same as above; third 5 weeks after first.	do.....	1916	1	1	.68	67.52	.68	67.52	.68	67.52
One application when grape berries are touching.	do.....	1916		3	5.25	23.39	33.95	75.16	18.71	51.29
One application 5 weeks after fall-ing of blossoms.	(¹).....	1916	1	1	19.97	55.53	19.97	55.53	19.97	55.53

¹ Same as above, except arsenate of lead, 2½ pounds, and resin fish-oil soap instead of laundry soap.

FACTORS DETERMINING THE TIME AND NUMBER OF APPLICATIONS.

The time and number of applications are determined not only by the seasonal history and habits of the grape-berry moth, but also by the development of the grape itself. Fortunately the times for spraying, most favorable in relation to the pest and also in relation to the crop, are nearly coincident. It is probable, therefore, that the vineyardist will find it most convenient to time his operations entirely by the development of the fruit.

The first spraying probably destroys the largest number of first-brood larvæ, for it is applied just before they begin hatching in numbers. Besides these, it also destroys some larvæ which hatch before the blossoms fall and are feeding in the cluster, but have not entered a grape berry. Following this application the grapes grow very rapidly and the larger part of the berry surface does not long remain covered. But as at this time the majority of the larvæ enter the berry at the stem end, where the spray always collects, comparatively few escape.

The second application is made after first-brood hatching begins to decline, but it is effective against the second brood also. As soon as the berries begin to touch, the majority of larvæ begin entering at the points of contact instead of at the stem ends. Spray which is

applied at this time is especially apt to collect at these places again, at which point it may be most effective later. It also covers the berry, and since there is comparatively little growth following this, it remains over the larger part of the surface until it is weathered off, or for about two months. Thus it remains effective during the period when the greater part of the second-brood larvæ hatch. As shown by the single-spray applications in 1916, this second spraying is practically as effective against the second-brood larvæ as is one applied three weeks later, just as they are beginning to hatch.

Larvæ which succeed in entering the first berry may be poisoned upon moving to a second. Larger larvæ seldom consume enough poison to prevent their entering the grape berry, but may be found dead in the berry a day or two later, whereas those that have reached the fourth stage are seldom susceptible to poison in the amounts in which it is to be found, after weathering, on sprayed grapes.

If this schedule is followed closely, the places on the grape berry at which the majority of the larvæ would normally enter should be well covered with poison, and the surface of the berry as a whole will be covered for a longer time than by two sprayings applied at any other time. If the first application were made earlier, before the falling of the grape blossoms, most of the poison would be lost with the shedding of the floral parts, and the application would be comparatively ineffective. If the second application were made earlier, while the berries were still growing rapidly, it could not cover the surface of the berries permanently nor could it collect at the points where the berries would touch, and while it might destroy more of the first brood, it would be almost entirely ineffective against the second. Hence no variation in the time of these two applications is advisable.

RELATION OF DIFFERENT GRAPEVINE TRAINING SYSTEMS TO SPRAYING.

The system of pruning and training a vineyard must be largely determined by horticultural considerations. Nevertheless the different systems greatly affect the facility with which the grapes may be sprayed and in other ways are related directly to the control of insect pests. To determine the relation to grape-berry moth control of five of the more important systems, a small block in Mr. A. P. Bartlett's vineyard was used in 1916. In all of the other spraying experiments the vines had been trained according to the Chautauqua system. This block was trained by the owner especially for this experiment according to the Four-cane Kniffin, Munson, Umbrella, High-renewal, and Chautauqua systems.

As there may be many who are not familiar with all of these vine-training systems the following brief descriptions have been compiled from the papers of Husmann (15) and Gladwin (14).

Chautauqua system.—This is the system used most frequently in the Erie-Chautauqua grape belt. The stem reaches only to the lowest wire from which permanent arms to support the canes are carried right and left along the lower wire. The canes, usually about 4, are carried upward and tied to the upper wire or wires.

High-renewal system.—The head of the vine reaches only the lowest wire of the trellis, and the canes are tied right and left along this wire. The fruiting shoots growing from these canes are trained upright and fastened to the wires overhead.

Four-cane Kniffin system.—The stem is carried directly to the top wire of a two-wire trellis. Two canes about the level of each wire are tied right and left along each wire.

Umbrella system.—This system differs chiefly from the Kniffin in that two canes are left instead of four. They are started at the upper wire and the extremities are tied down to the lower wire.

Four-cane Munson system.—This system differs from the others mentioned in that it requires an overhead trellis. Across the top of each post a crossbar 20 inches long is fastened and outer wires are fastened at the ends of these crossbars, while an inner wire is fastened to the post about 6 inches lower down. A single stem is carried to the inner wire and four canes are left, one carried in each direction along each wire.

Two regular first-brood applications with "trailers" were made. Vines trained according to any of these systems could be sprayed thoroughly and the difference in final counts is not significant, but the ease with which the applications were made is of considerable importance.

The Kniffin and Munson systems were much the easier to spray. The time required was about 15 per cent less than that required for the Chautauqua system. These systems had the advantage of having no upright shoots or canes to interfere with a free action of the spray rod. The fruit, although well protected by leaves above at the time of spraying, was well exposed below. The bunches hung, in the Kniffin system in two layers, one below each wire, and in the Munson system just below the trellis, and consequently were easy to find. The Munson system had the disadvantage of producing a dense shade, and consequently favoring grape-berry moth infestation.

In contrast to this, the Chautauqua system presented the disadvantage of upright canes, which interfered with free action of the spray rod and with fruit arising from anywhere up and down these canes. The clusters were well protected by leaves and often isolated, and greater care was necessary in finding them and covering them with spray.

The umbrella system with the canes bent down from the upper wire to the lower presented a difficulty in spraying similar to that of the Chautauqua system, although it seemed slightly easier to spray.

The high-renewal system was much more difficult to spray owing to the tendency of the rods to catch in the numerous upright shoots.

SUMMARY OF IMPORTANT FACTORS IN SPRAYING PRACTICE.

The most important factors in spray practice to control the grape-berry moth, shown by the final counts in 28 of the 49 experimental plats of three years, are summarized briefly in Table 24. Factors of minor importance such as a complete comparison of adhesives and value of nicotine sulphate are omitted. In addition, the plats in the experiment in the Phillips vineyard, 1914, because of the erratic infestation, and the plats in the Miller and Carlborg vineyard, 1915, which were affected by rain, are excluded.

TABLE 24.—*Relative efficiency of spraying measures tried.*

Spray mixture, method of application, and spray schedule followed.	Years tried.	Number of sprayed plats.	Infested fruit.	
			Average in sprayed plats.	Average in adjacent unsprayed checks.
I. Arsenate of lead, paste, 3 pounds, or powder, 1½ pounds; laundry soap, 1 pound; Bordeaux mixture, 3-3-50. Applied with "trailers" immediately after blossoms had fallen and again when grape berries were just touching (or about 2 weeks later).....	1915, 1916	7	<i>Per cent.</i> 4. 12	<i>Per cent.</i> 50. 03
II. Same as I except arsenate of lead omitted.....	1915	1	33. 31	28. 80
III. Same as I except adhesive omitted.....	1915	1	21. 05	28. 80
IV. Same as I except Bordeaux mixture omitted.....	1916	1	4. 01	88. 74
V. Same as I except arsenate of lead increased to 5 pounds (paste) or 2½ pounds (powder).....	1915, 1916	6	3. 34	54. 90
VI. Same as I except resin fish-oil soap used instead of laundry soap, 1 pound.....	1916	1	2. 14	55. 53
VII. Same as I except fish-oil soap (without resin) used instead of laundry soap, 2 pounds.....	1915, 1916	3	3. 95	42. 84
VIII. Same as I with addition of a third application 5 weeks after first.....	1916	1	. 68	67. 52
IX. Same as I (including only the plat adjacent to VI).....	1916	1	1. 57	79. 72
X. Same as I except first application omitted.....	1916	3	18. 71	51. 29
XI. Same as I except "set nozzles" used in first application instead of "trailers".....	1916	2	12. 87	52. 04
XII. Same as I except "set nozzles" used in both applications instead of "trailers".....	1915	1	20. 41	28. 80
XIII. Same as I except adhesive omitted and "set nozzles" used in both applications instead of "trailers".....	1914	1	26. 70	31. 80

This table shows that both arsenate of lead and soap are essential factors in the spray mixture, while Bordeaux mixture is of little importance. An increase in the amount of arsenate of lead is usually of little value, and variation among the three kinds of soap used is not an essential consideration. Two applications effect a practically satisfactory control so that the advantage of a third application is insignificant. The omission of the first application, or making it

with "set nozzles" instead of with "trailers," furnishes on the average only a partially satisfactory measure, while complete substitution of "set nozzles" for "trailers" is entirely unsatisfactory.

SPRAY COMBINATIONS

A combination of sprays may be made, to control, besides the berry moth, practically all other important enemies of the grape in this region—the grape rootworm, the grape leafhopper, and the powdery mildew. These spraying recommendations for the control of enemies of the grape other than the grape-berry moth are based on recommendations of other investigators,¹ and were employed incidentally in connection with the berry-moth experiments.

The time of the first spray application for berry moth, just after the grape blossoms fall, during the seasons of 1914, 1915, and 1916, has been from 2 to 4 days before the appearance of the rootworm beetles. Without change of time or mixture this application is effective against the rootworm also. If this application is intended as rootworm control also, care should be taken to cover the upper surface of the foliage, for unless extra attention is given to this it is apt to be done less effectively with "trailers" than with "set nozzles." In exceptional instances an extra application for rootworm control may be necessary. This combination must not be attempted if it is desired to add molasses or sugar to the rootworm spray, as mixtures containing sugar are very soluble and wash off the vines readily. Furthermore, a combination of sugar with Bordeaux mixture is apt to burn foliage.

The second berry-moth spray, applied when the berries are just touching, may be made effective also against the grape leafhopper by the addition of nicotine sulphate (40 per cent) at the rate of 1-1,600 ($\frac{1}{4}$ pint to 50 gallons.)

By the addition of Bordeaux mixture in these two applications, powdery mildew also can be controlled. These two applications of Bordeaux will be useful against black rot and downy mildew also, where these occur, although an additional earlier spray will be necessary for the control of these diseases.

COST.

The cost of spraying material and labor required to control the grape-berry moth, if applied to control the berry moth alone, is about \$5 per acre. In computing this cost it is assumed that an average of 6 acres are sprayed per day and that 150 gallons of liquid are applied per acre. This average may not be maintained if the water supply is inconveniently situated and the spraying machinery is not kept in condition, but delays due to these sources are not nor-

¹ See Quaintance and Starr (12), Johnson and Hammar (13), Johnson (17), and Hartzell (18).

mally necessary. These figures do not include interest on money invested in the spraying machine, depreciation, breakage, or incidental costs of operation, such as gasoline and oil, since these vary greatly. The details of cost for a single application are as follows:

Materials for 150 gallons of spray mixture:

Arsenate of lead (paste), 9 pounds, 8 cents per pound.....	\$0.72
Lime, 3 pounds, $\frac{1}{3}$ cent per pound.....	.01
Resin fish-oil soap, 3 pounds, $6\frac{1}{4}$ cents per pound.....	.19
Labor, 3 men, $\frac{1}{2}$ day at \$2 per day.....	1.00
1 team, $\frac{1}{2}$ day, at \$3 per day.....	.50
	2.42

For the two applications the cost would be \$4.84 per acre.

The entire cost, however, need not be charged to berry-moth control if a combination spray is used. These two spray applications are necessary in the majority of vineyards to secure the greatest possible profits, even if the berry moth is not present. In a vineyard where control measures are already employed against the rootworm, leafhopper, and powdery mildew, the additional cost per acre in controlling the berry moth would be as follows:

Extra cost of labor for using "trailers" instead of "set nozzles" in the first application.

Labor cost with "trailers" (see above).....	\$1.50
Labor cost with "set nozzles," 1 man and team $\frac{1}{2}$ day at \$5 per day.....	.675
	\$0.825
Arsenate of lead (paste), 9 pounds for second application, at 8 cents per pound.....	.72
Soap, 6 pounds (2 applications), at $6\frac{1}{4}$ cents per pounds.....	.375
	1.920

Thus, if spraying for rootworm, leafhopper, and mildew is properly done the extra cost of spraying for the grape-berry moth is only \$1.92 per acre.

SUMMARY AND RECOMMENDATIONS.

The grape-berry moth can be controlled by spraying. Other methods will reduce berry-moth infestation, and some of them can be employed profitably to increase the efficiency of spraying, but none offers a dependable control in commercial vineyards.

Gathering and destroying grape leaves in the fall is of little use in berry-moth control.

Bagging grape clusters immediately after the setting of the fruit will exclude the berry moth and prevent infestation, but the expense is prohibitive in commercial vineyards in this region and may be used advantageously only in garden vineyards. Hand picking of grape berries infested by first-brood larvæ, if done by competent labor, will reduce berry-moth infestation, but except in extraordinary cases

will not control it. When spraying can be employed these measures are unnecessary.

A number of other measures reduce infestation and generally may be employed as a part of vineyard practice without additional expense. When commercial vineyards are infested, the worst areas should be harvested as early as possible and the "trimmings" removed, to secure the largest weight for the crop and to remove as many larvæ as possible from the vineyard. Clearing away brush in the neighborhood of a vineyard will destroy the protection for hibernating pupæ with an ultimate reduction in infestation. When it is in keeping with cultural practice, pupæ hibernating under the vines should be covered with earth in the spring by plowing, and this covering should remain until the period of blossoming of the grapes, when it should be removed with a horse hoe. This plowing should not be allowed to interfere with spraying.

These practices, it must be remembered, while reducing infestation, will not control it, and they should not be expected in any way to take the place of spraying.

The following spraying practice has been found most satisfactory:

The spray mixture—

Arsenate of lead—

Paste.....	pounds..	3
Or powder.....	do....	1½

Resin fish-oil soap.....	do....	1
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Bordeaux mixture—

Copper sulphate.....	do....	3
Lime.....	do....	3

Water.....	gallons..	50
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Method of application, with "trailers":

Spray schedule—

First application, immediately after falling of grape blossoms.

Second application, when grape berries are just touching (or about two weeks later).

Under some conditions it may be desirable to modify the spraying practice outlined above.

In case of extremely heavy infestation the amount of arsenate of lead should be increased to 5 pounds (paste) or 2½ pounds (powder), at least in the last application.

If resin fish-oil soap is not available a laundry soap containing resin may be substituted in its place. Laundry soaps, however, vary greatly in their sticking and spreading qualities, and great care should be used in selecting those best suited to this purpose. Whatever soap is used, care must be taken to have it thoroughly dissolved before adding it to the spray mixture to prevent clogging of the spraying machinery.

The use of Bordeaux mixture, while not having a direct effect upon the berry moth, is recommended, to prevent burning of the grape

foliage by the combination of arsenate of lead and soap. Lime at the rate of 1 pound to 50 gallons may be substituted instead. Since it is very rarely that the fungicidal spray can be omitted with profit, the use of Bordeaux mixture is preferred.

This spraying combination should control any infestation of the grape-berry moth, such as the writer has observed during three seasons in the Erie-Chautauqua grape belt, and has been applied successfully under very unfavorable weather conditions. If, however, through faulty spray materials or work, or adverse weather at the time of spraying, these applications fail to control the first-brood larvæ, they may be supplemented by a third application five or six weeks after the first, with the understanding that the fruit is likely to show heavy staining at time of harvest. This staining may be reduced by omitting Bordeaux mixture from the solution applied and using instead 1 pound of lime in 50 gallons of water.

In case the foliage is very light at the time of the first application, expenses may be reduced somewhat by using "set nozzles" at this time and using "trailers" only for the second application. Single spray applications, either at the time the grape berries are just touching or about three weeks later, will reduce the infestation and in some instances control it. Such measures to reduce expenses of spraying, however, are dangerously likely to fail in reducing the infestation satisfactorily, and should be adopted with great caution.

Spraying operations will be facilitated greatly by training the vines so that the clusters may be reached most quickly and covered with spray. In a limited experiment the Kniffin system seemed most satisfactory for this purpose.

The applications required for the control of the grape-berry moth are so timed that they may be combined with applications to control the grape rootworm, grape leafhopper, and powdery mildew, and some of the applications for downy mildew and black rot also may be combined with them. Nothing need be added to the spray solution for rootworm control; nicotine sulphate (40 per cent) at the rate of 1 to 1,600 should be added to the second application for leafhopper control; and Bordeaux mixture should be used in both applications for fungous diseases.

The cost of spraying to control the grape-berry moth need not exceed \$5 per acre. If the applications are made to control other pests as well, the charge against the berry-moth control should be considerably less.

It should be borne in mind that unless the proper spray mixture is applied at the right time and the clusters are thoroughly covered, the work is of little value.

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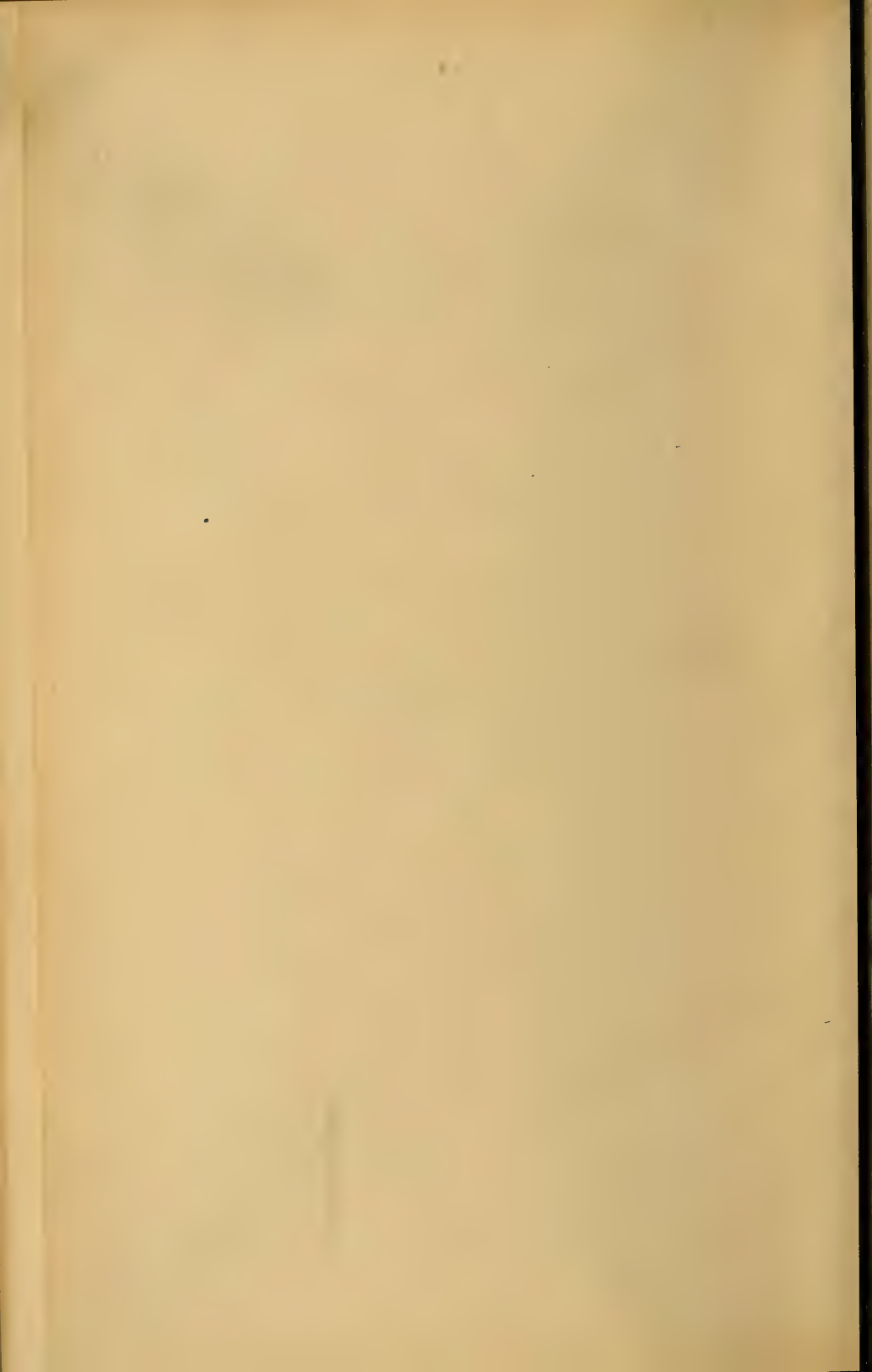
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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 526

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

August 28, 1918

EXPERIMENTS WITH SINGLE-STALK COTTON
CULTURE IN LOUISIANA, ARKANSAS
AND NORTH CAROLINA

By

P. V. CARDON, Assistant Agronomist

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1918

THE RESULTS presented in this report were obtained in 1915 under an informal cooperative agreement between the Office of Acclimatization and Adaptation of Crop Plants, of the Bureau of Plant Industry, and the Office of Extension Work in the South, of the States Relations Service.

The writer wishes to acknowledge the cordial cooperation of the various State, district, and county agents of the last-named office and the assistance rendered by the many farmers who were interested in the experiments.

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 527

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C.

PROFESSIONAL PAPER

July 26, 1917

SOME EXERCISES IN FARM HANDI-
CRAFT FOR RURAL SCHOOLS

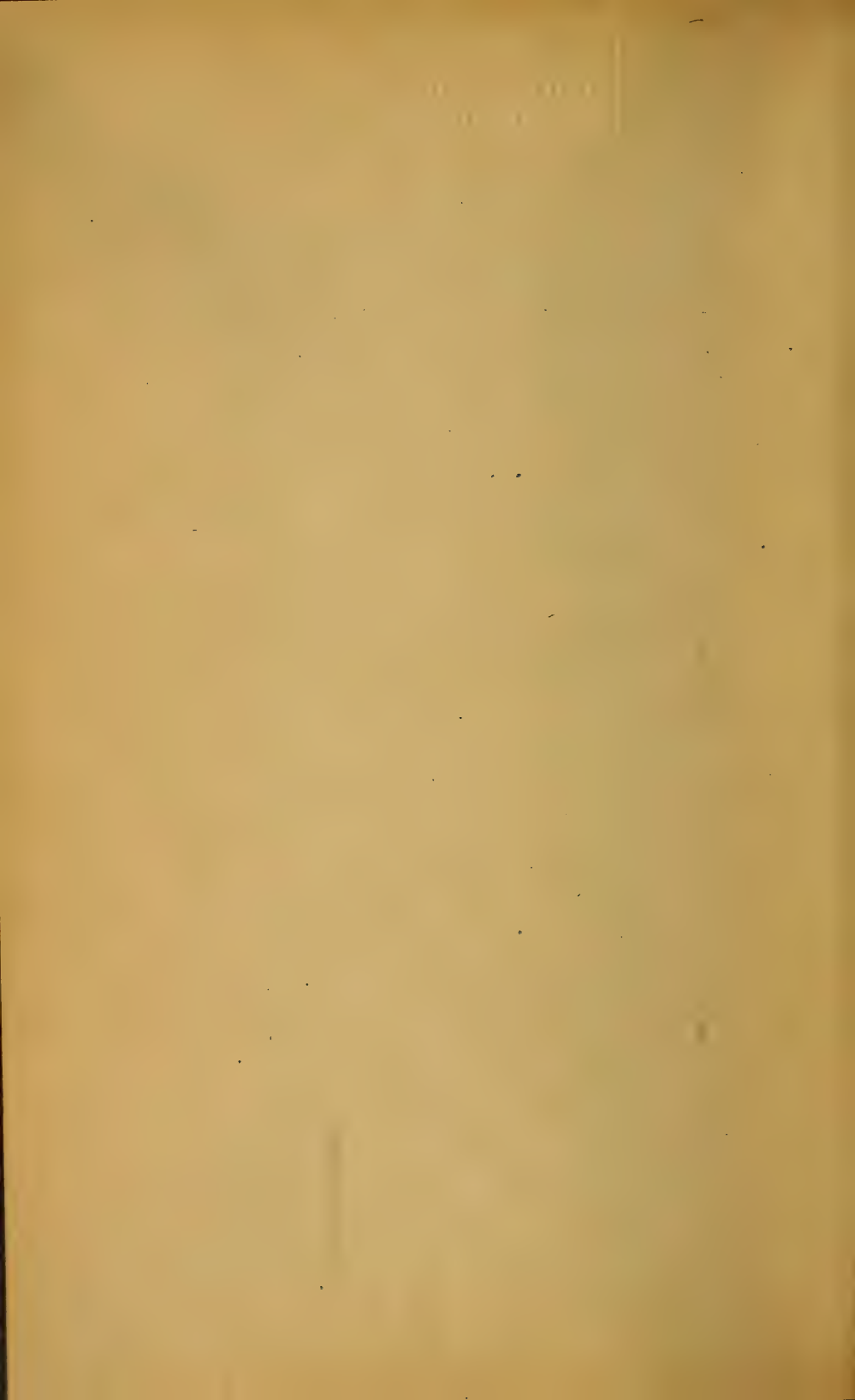
By

H. O. SAMPSON, Assistant in Agricultural Education

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 528

OFFICE OF THE SECRETARY

Contribution from the Office of Farm Management
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Washington, D. C.



April 13, 1917

SEASONAL DISTRIBUTION OF FARM LABOR
IN CHESTER COUNTY, PA.

By

GEORGE A. BILLINGS, Agriculturist

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 530

Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.



May 8, 1917

THE ORGANIZATION AND MANAGE-
MENT OF A FARMERS' MUTUAL FIRE
INSURANCE COMPANY

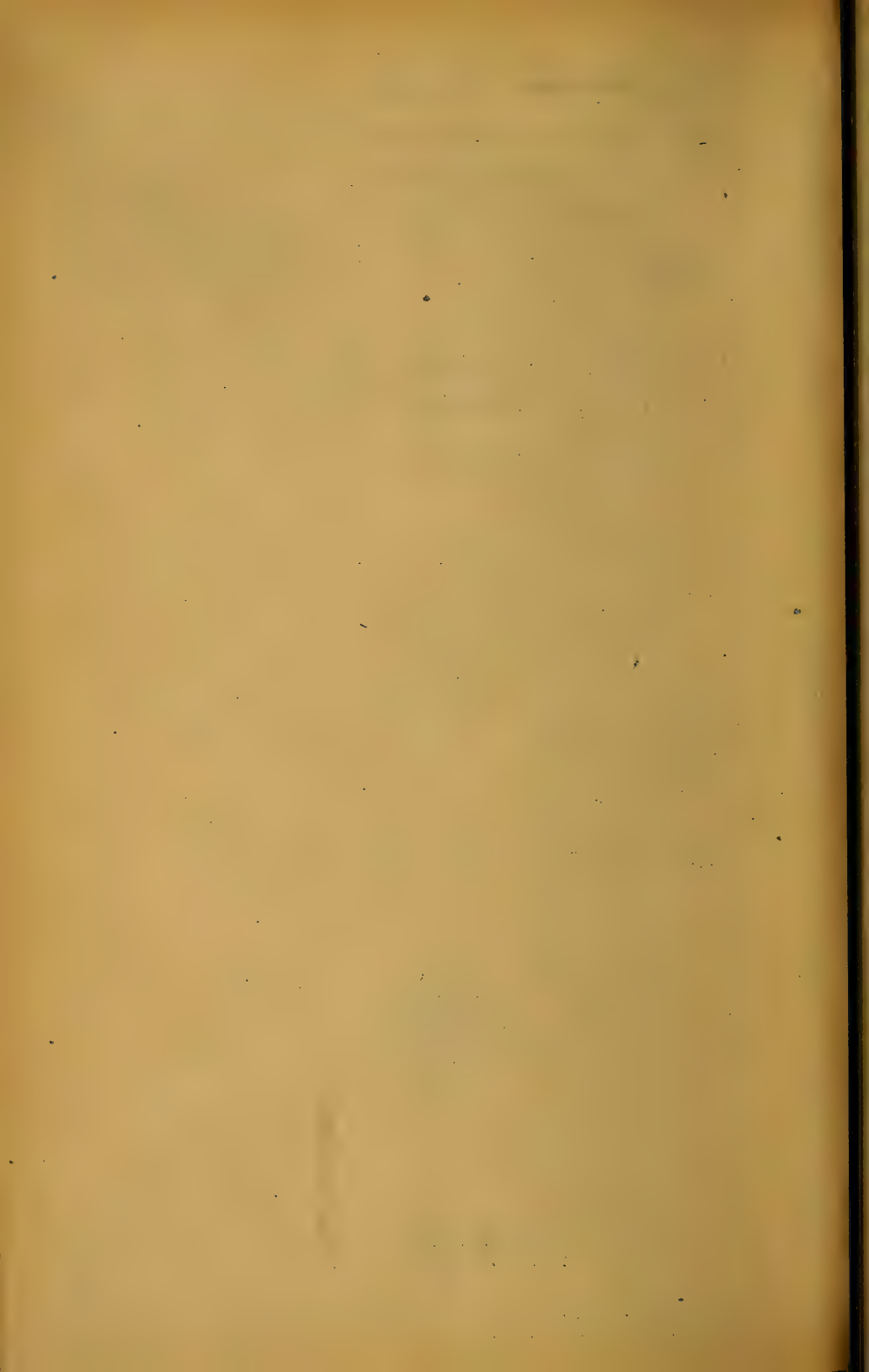
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V. N. VALGREN, Investigator in Agricultural Insurance

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UNITED STATES DEPARTMENT OF AGRICULTURE
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Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.

PROFESSIONAL PAPER

October 13, 1917

THE EXPANSION AND CONTRACTION
OF CONCRETE AND CONCRETE
ROADS

By.

A. T. GOLDBECK, Engineer of Tests, and F. H. JACKSON, JR.
Assistant Testing Engineer

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 536

Contribution from Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

January 26, 1918

THE MEDITERRANEAN FRUIT FLY
IN HAWAII

By

E. A. BACK, Entomologist, and C. E. PEMBERTON,
Assistant Entomologist, Mediterranean and
other Fruit-Fly Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 540

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C. PROFESSIONAL PAPER July 27, 1917

**A FIRST YEAR COURSE IN HOME
ECONOMICS FOR SOUTHERN
AGRICULTURAL SCHOOLS**

By

LOUISE STANLEY, Professor of Home Economics
University of Missouri

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Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

October 31, 1917

THE RED SPRUCE:
ITS GROWTH AND MANAGEMENT

By

LOUIS S. MURPHY, Forest Examiner

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 545

Joint Contribution from the Forest Service, HENRY S. GRAVES, Forester
and the Bureau of Plant Industry, WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

October 8, 1917

IMPORTANT RANGE PLANTS:
THEIR LIFE HISTORY AND FORAGE VALUE

By

ARTHUR W. SAMPSON, Plant Ecologist, Forest Service

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1917

PREFATORY NOTE.

Early in its administration of the National Forests the Forest Service was confronted with the problem of restoring the vegetation on many areas on which the natural ground cover had been completely or partially wiped out by destructive overgrazing before the areas were included in National Forests. In order to secure the fundamental information on which beneficial changes in the practice of grazing on such areas might be based the Forest Service joined the Bureau of Plant Industry in 1907 in a cooperative project of grazing investigations. Several important reports have been published, embodying the results of these various field studies, and the changes that have been made in the administration of grazing on the National Forests in accordance with the results of the investigations have brought about conspicuous improvement in the ground cover, great advance in the protection of watersheds, and important increase in the number and quality of stock grazed. A part of the original plan of investigation was to make a detailed study of the life history of each important grazing plant for the special purpose of determining its reproductive season, from the sending up of the flower stalk to the maturing of the seed, and the period necessary to enable the new seedlings to reach a size and vigor sufficient to withstand moderate trampling by stock. In the course of these studies a very large amount of detailed information about the important grazing plants was acquired which could not be used in the more general reports already published. In the paper now presented for publication a portion of this detailed information is given, in a form suited to the needs of forest officers and of stock owners who desire to familiarize themselves with the habits and requirements of the plants upon which their animals subsist. Such knowledge is necessary to the highest success in their business just as a knowledge of the habits and requirements of cultivated plants is necessary to the highest success in the business of the farmer. For the first time in the history of grazing-plant literature the information needed to accomplish this result has been acquired and presented for public use.

FREDERICK V. COVILLE,
Botanist, Bureau of Plant Industry.

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 547

Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.



September 19, 1917

**COOPERATIVE PURCHASING AND MARKETING
ORGANIZATIONS AMONG FARMERS IN
THE UNITED STATES**

By

**O. B. JESNESS, Assistant in Cooperative Organization, and
W. H. KERR, Investigator in Market Business Practice**

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 550

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.



August 9, 1917

CONTROL OF THE GRAPE-BERRY MOTH
IN THE ERIE-CHAUTAUQUA
GRAPE BELT

By

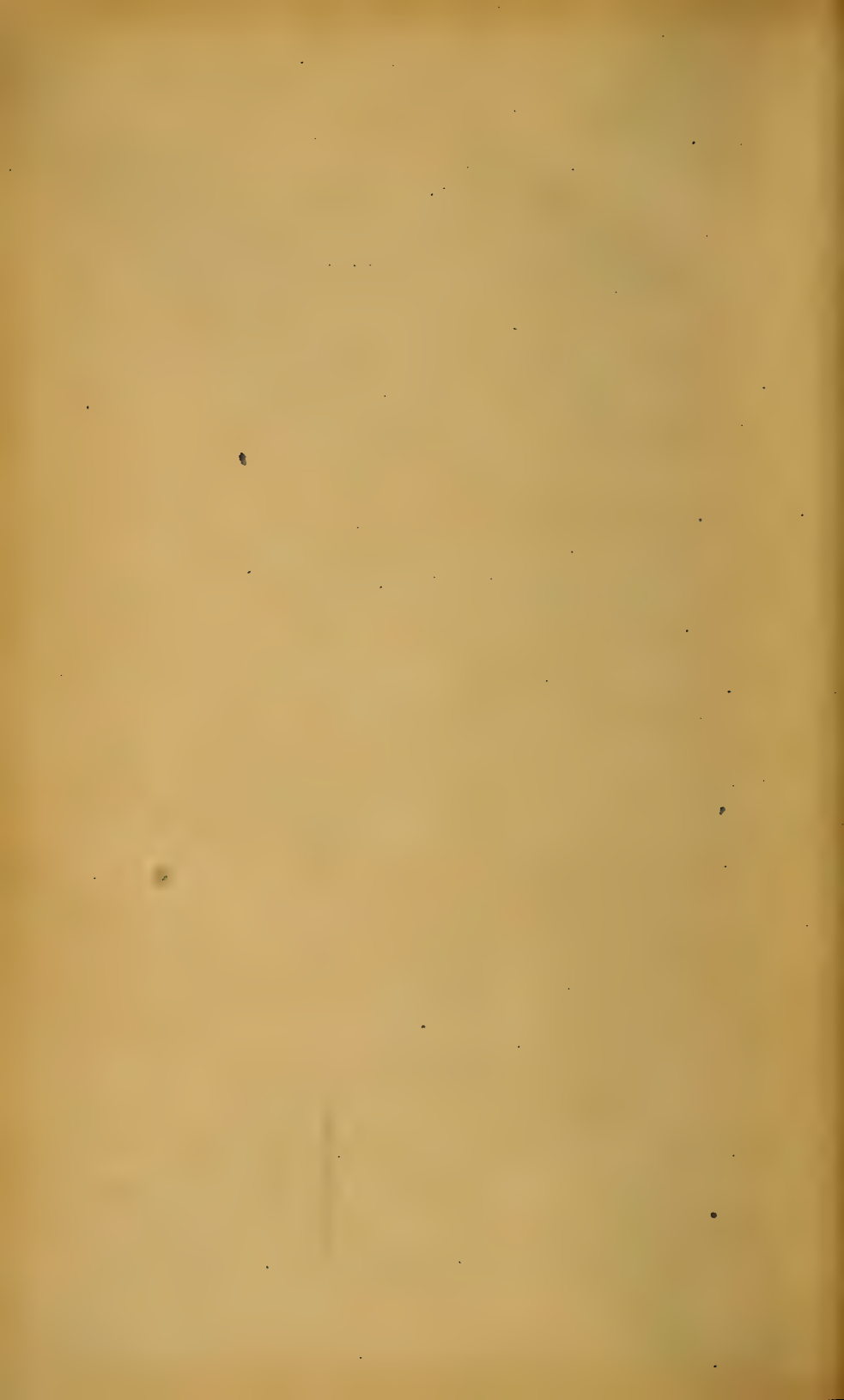
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Fruit Insect Investigations

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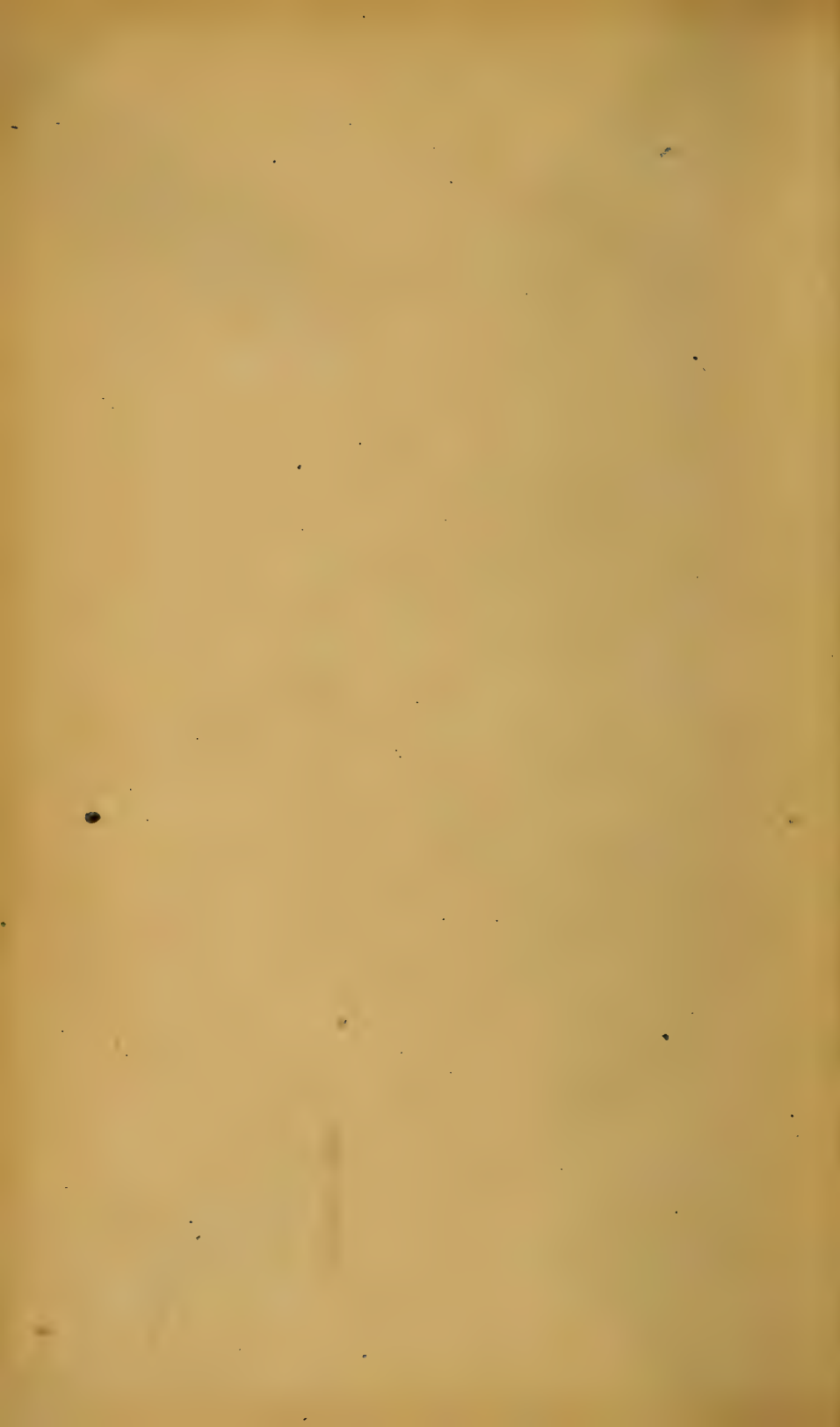
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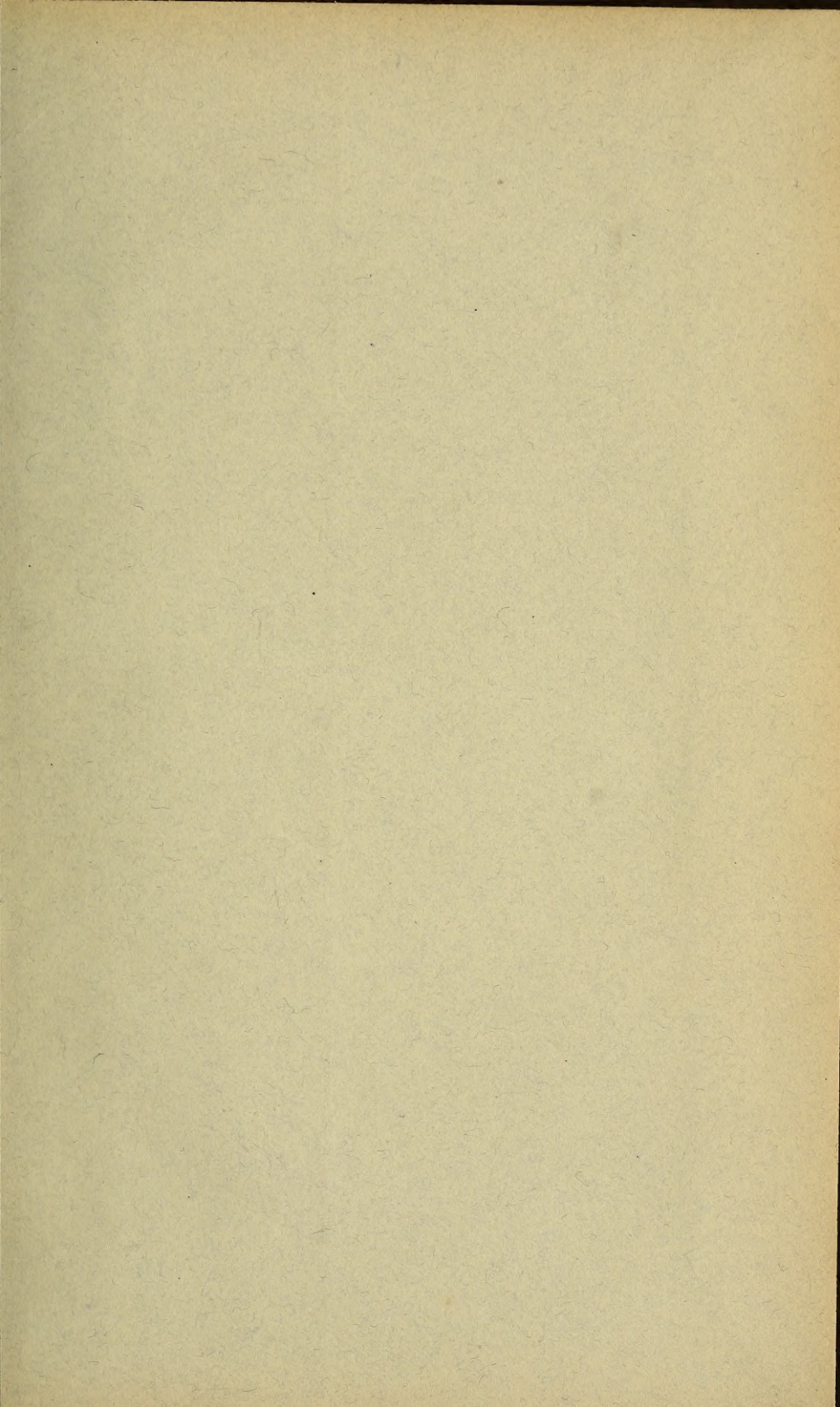


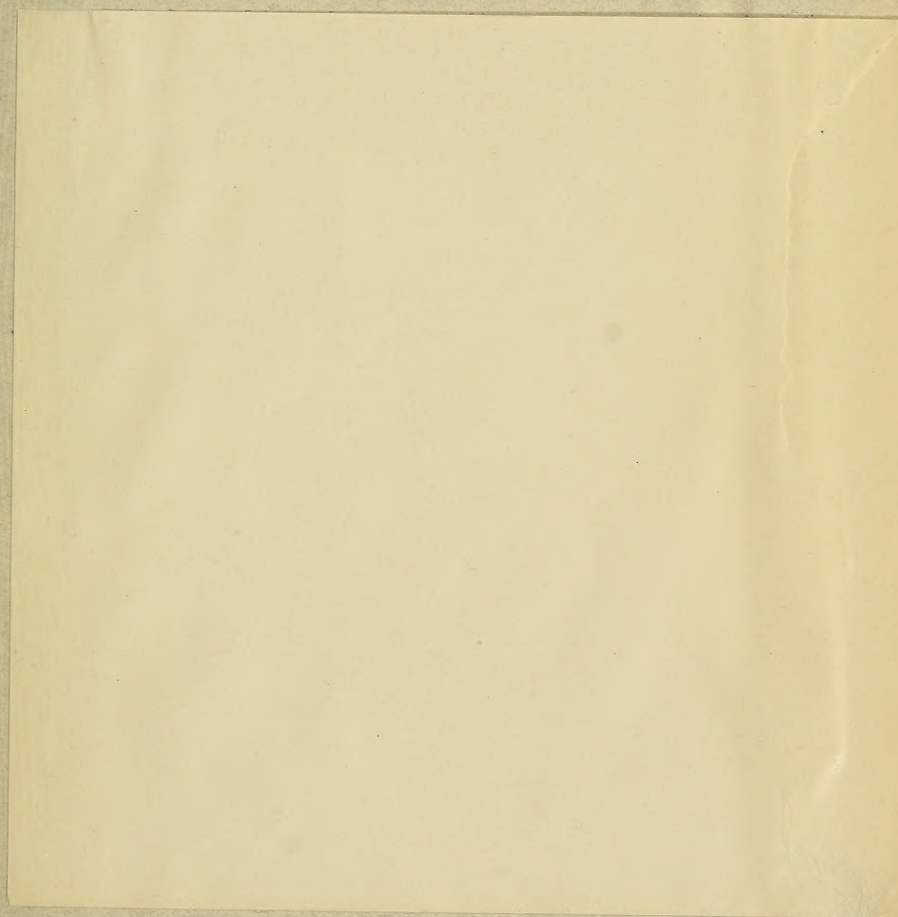












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